STARS in a CLUSTER

Edited by

W. TOBIN and G. M. EVANS

STARS IN A CLUSTER

STARS IN A CLUSTER:

MT JOHN UNIVERSITY OBSERVATORY

TENTH ANNIVERSARY OF THE McLELLAN TELESCOPE

HUNDREDTH ANNIVERSARY OF THE TOWNSEND TELESCOPE

PUBLICATIONS 1979 – 1995

Edited by
W. Tobin & G.M. Evans

Department of Physics & Astronomy
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Front cover: *Time-lapse photography and a rotating dome reveal the McLellan One-metre Telescope under η Carinae and the stars of the Southern Cross (photo: R.F. Gledhill).*

Back cover: *The Townsend Telescope, old University site, Christchurch.*

Page 2: *The Southern Cross and the Coalsack, from the* Canterbury Sky Atlas.

The editors thank all those who have assisted the production of this book, especially Mike Bradstock of the Canterbury University Press.

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PREFACE

Ka titiro ahau ki Au rangi, ki te mahi a Ou maihao,
ki te marama, ki nga whetu, i hanga nei e Koe;
He aha te tangata i maharatia ai e Koe?
(Waiata 8:3,4)

When I consider Thy heavens, the work of Thy fingers,
The moon and stars, which Thou hast ordained;
What is man that Thou dost take thought of him?
(Psalms 8:3,4)

For almost 30 years, it has been my privilege to be the MP for the large Southern Maori electorate which encompasses the entire South Island and a section of the North. Mt John itself, the University of Canterbury at Christchurch and the former DSIR Physics and Engineering Laboratory at Lower Hutt, where the McLellan Telescope optics were designed, are all within my electorate.

Of the many beautiful places of tranquility in my constituency, Mt John (*Te Maunga o Hoani, te Apōtoro*) is utterly unique. Only there have I glimpsed beyond what *eye* can see, into the vast expanses of the cosmos.

My husband, scientist and astrophysicist Dr Denis Sullivan, has enticed me to gaze at the stars through the McLellan Telescope—New Zealand's largest—at Mt John. I reflected on the reason why, on clear nights, I don't spend time appreciating the stars. The fact is, relatively few people ever stop and gaze upwards at nights, yet my Polynesian forebears made a particular study of the stars—their navigational aids—as they traversed the expanse of the the oceans to'ing and fro'ing to these antipodean islands we now call *Aotearoa* and *Te Waipounamu* (New Zealand).

They also did their fishing and planting by the stars and planets, and particularly by the phases of the moon. A few still do, today.

In the area surrounding Mt John, the earliest settlers were the ancient *Waitaha*. They possess the distinction of having never crafted weapons of war. Apostles of peace, who practised non-violence, they came to this area in season to harvest their special delicacies, fishing for eels and hunting weka. Next came the *Ngati Mamoe*. Then the *Ngaitahu*. All are among my forebears. For each people, this was a special place.

Haere mai! Naumai! Noho ora mai! Titiro atu ki nga whetu me te marama!
Naaku, na:

Hon. WHETU MARAMA TIRIKATENE-SULLIVAN, ONZ
MP for Southern Maori (*Te Tai Tonga*)

Stars in a cluster,
Crosses of snow,
Under their lustre,
Fearlessly go.

J.C. Andersen (1873-1962), in praise of the recently adopted national ensign in 1902. Andersen was a noted scholar, writer and lecturer on New Zealand and its people. He later became the first librarian at the Alexander Turnbull Library in Wellington.

CONTENTS

Introduction

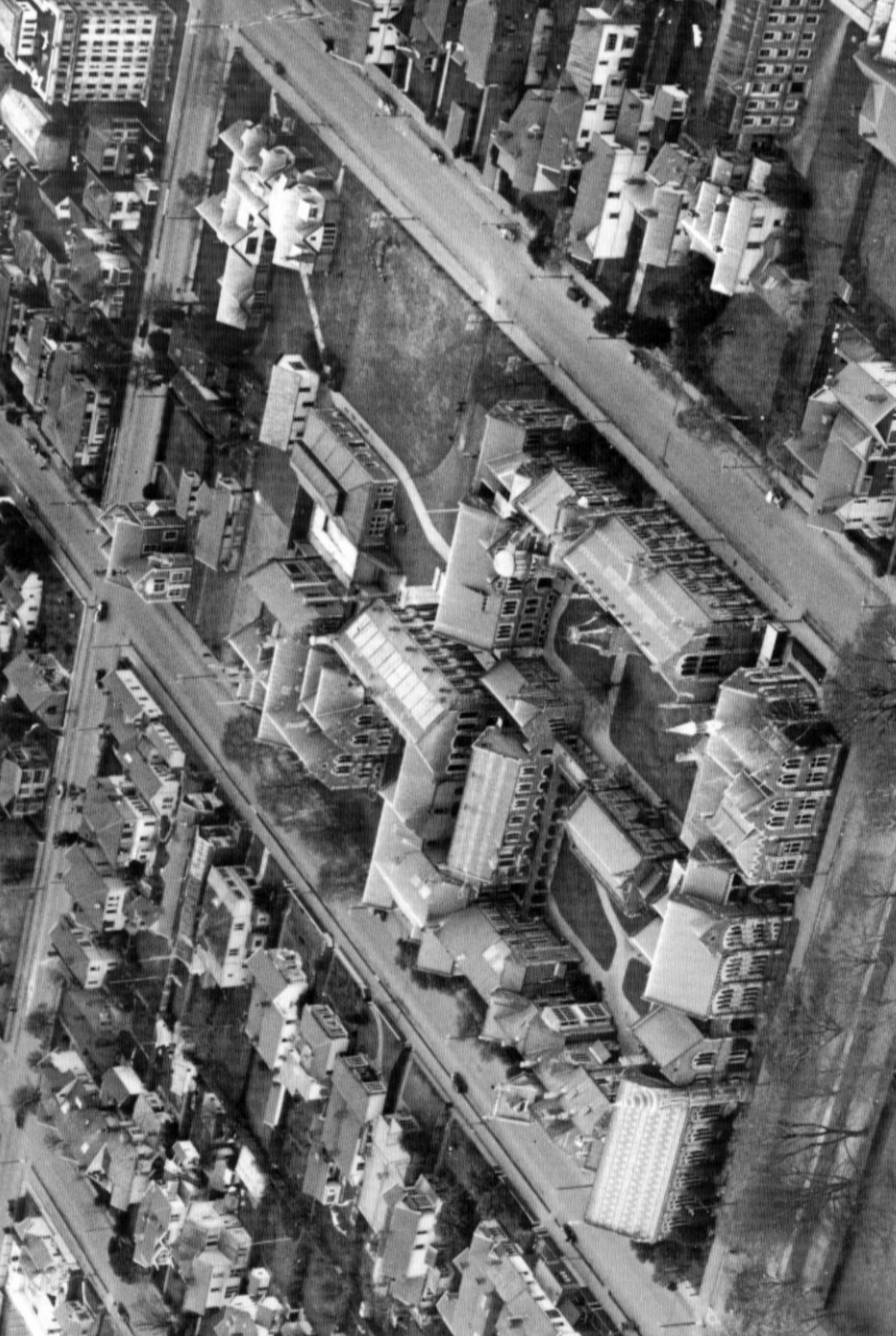
The Māori creation myth in which Rangi is raised up to form the inverted bowl of the sky shows that the celestial vault has been a preoccupation since the beginning of human habitation of these islands. Astronomy continues to excite wide public interest,as a glance at any newspaper will show, where astronomy always figures prominently among the science features.

Scientific astronomy began in New Zealand with the foundation of the Colonial Observatory in Wellington in 1868. The impetus was purely practical—timekeeping; and Lyttelton's Time Ball Station, built in 1876, is a remnant of the network by which the astronomers' signals were distributed to mariners and others requiring accurate time.

The University of Canterbury's involvement in astronomy dates back to Alexander Bickerton, who in 1874 took up the first professorship offered by the University's precursor, Canterbury College. Bickerton was a colourful character, and a popular speaker (he believed science classes should be 'as entertaining as a music hall and as sensational as a circus'), but his liberal attitudes led him into conflict with the conservative college authorities, and ultimately led to his dismissal in 1902. Bickerton's professorship was nominally in chemistry, but his responsibilities were much wider. It was during Bickerton's stewardship that Mr James Townsend Jnr donated a six-inch refracting telescope to the College. This telescope was installed in 1896 and is still in use for public viewing. It seems, however, that Bickerton had little to do with Townsend's gift; Bickerton's greatest claim to astronomical fame (or infamy), was his 'Partial Impact' theory, with which he tried to explain the nature of novae (which are stars that shine brightly for a brief time) as well as formation of the solar system and the Galaxy.

Partial impact was never accepted by astronomers and is long discredited. (One reviewer commented on Bickerton's 'strange mixture of the scientist and the completely uninformed amateur.') A more positive legacy of Bickerton's professorship is the work and career of one of his students, Ernest Rutherford, who was steered by Bickerton into physics research. For his work on radioactivity and the nucleus, Rutherford was awarded the Nobel Prize, elevated to the peerage, and finally buried in Westminster Abbey. Bickerton's less-revered ashes are immured in the Great Hall of the old Canterbury College building (now the Arts Centre, Christchurch).

Opposite: Canterbury University College with the Townsend dome in the late 1930s.



Frank Bateson checks the air temperature on Mt John during a chilly day in the 1960s.

The modern era of research in optical astronomy at the University of Canterbury began on 30 July 1963 when the Universities of Canterbury and Pennsylvania announced that they would establish an observatory on Mt John as a joint venture. This was the result of a behind-the-scenes campaign by Frank Bateson, who was then appointed Mt John Astronomer-in-Charge and began building up the Observatory. Initially it was the University of Pennsylvania that made most use of the Observatory, but as US astronomers developed southern observatories in Chile, their participation in Mt John dwindled while that of the University of Canterbury grew.

A momentous day in the history of Mt John was Friday 11 July 1986, when the McLellan One-metre Telescope was inaugurated amid winter snow. This telescope is the largest in the country and was built entirely within New Zealand. The optics were designed in Lower Hutt by Norman Rumsey of the Physics & Engineering Laboratory of the Department of Scientific & Industrial Research. They were then constructed by Garry Nankivell of the same Laboratory during a 6-month secondment to the Department of Physics in Christchurch. The telescope's mechanical structure and dome were also designed and fabricated in the Department of Physics by Graeme Kershaw and Bruce Bradshaw, respectively, ably assisted by Morrie Poulton and many other of the Department's technical staff. The telescope was named in honour of Prof. Alister McLellan, who was Head of the Department of Physics from 1955 to 1983 (retiring in 1985). He was a strong supporter of the telescope project.

The McLellan Telescope has greatly increased the range and importance of the research projects that can be undertaken at Mt John. This is the result of a combination of two factors which result both in better quality observations, and in observations of a fainter and wider range of astronomical objects. One factor is the greater light-grasp of the telescope itself. The other is the much greater sensitivity of modern electronic detectors, the introduction of which followed hard on the heels of the inauguration of the McLellan Telescope at Mt John.

This book has been produced in part to celebrate the first decade of the McLellan Telescope and the first century of the Townsend Telescope. The principal goals of the University's astronomy programme are tertiary-level teaching and research of an international quality in astronomy and astrophysics.[1] The audience for these specialised activities is inevitably restricted and the reduced university funding of recent years means additional struggle is required to achieve them. Little in the way of time or money is left over to report activities at Mt John to the wider public. This is very regrettable, since all astronomers know that their science is of great interest to the lay person. However, thanks to generous grants from the Lottery Environment and Heritage Committee, the University of Canterbury, the Frank Bradshaw & Elizabeth Pepper Wood Fund, and the Kingdon-Tomlinson Trust (administered by the Royal Astronomical Society of New Zealand), it has been possible to widen the scope of this book, illustrate it with black-and-white photographs, cloak it in a colour cover, and distribute it to the original donors to the One-metre Telescope Appeal, to astronomical societies, and to public, secondary-school and other selected libraries throughout the country and elsewhere.

A series of articles aimed at the general reader is followed by lists of Mt John's astronomy publications since 1979. Most of these are principally of interest to the technical reader, but those aimed at the wider public, or about Mt John, will provide additional material for the general reader keen to delve further.

In 1992 the growth and success of astronomy at the University of Canterbury was recognized when the Department of Physics was renamed the Department of Physics & Astronomy. The authors and editors of this book hope that readers will find it an interesting and informative introduction to what is involved in professional astrophysical research and a record of some of what has been achieved in Canterbury and New Zealand astronomy in recent years.

WILLIAM TOBIN
GILL EVANS

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[1]The term *astrophysics* refers to attempts to understand the nature and properties of the universe and its contents via the application of the methods and quantitative laws of physics. *Astronomy* is also used in this sense, but the term can have other meanings. It can refer to the data collection and description of phenomena which are essential preliminaries to the formulation and testing of astrophysical interpretations. It is used for the study of planetary motions and other concerns of pre-20th century astrophysics. Finally, *astronomy* is frequently used to refer to the non-scientific enjoyment of the beauty and poetry of the night sky.

The University of Canterbury's Programme in Astronomy

The University of Canterbury's astronomy programme runs under the auspices of the Department of Physics & Astronomy. The goals of the programme are:

(1) Undergraduate teaching in astronomy as part of the course requirements for Bachelor's, Diploma in Science and Master of Science degrees,

(2) Training in research, and research, as components of Honours, Master of Science and Doctor of Philosophy degrees,

(3) Other research in astronomy and astrophysics by members of the academic staff, postdoctoral fellows, research assistants, and sabbatical and other visitors.

Research and teaching are inextricably mixed in a university; however the Mount John University Observatory is operated primarily in support of the second two of the above objectives.

The University's *Charter* notes universities have wider responsibilities beyond teaching and research. Subsiduary goals of the astronomy programme, implemented only when hard-pressed resources allow, include:

(4) Support for astronomy elsewhere in New Zealand and overseas, and

(5) Public education in astronomy.

The Department operates the Townsend Observatory in support of this last objective.

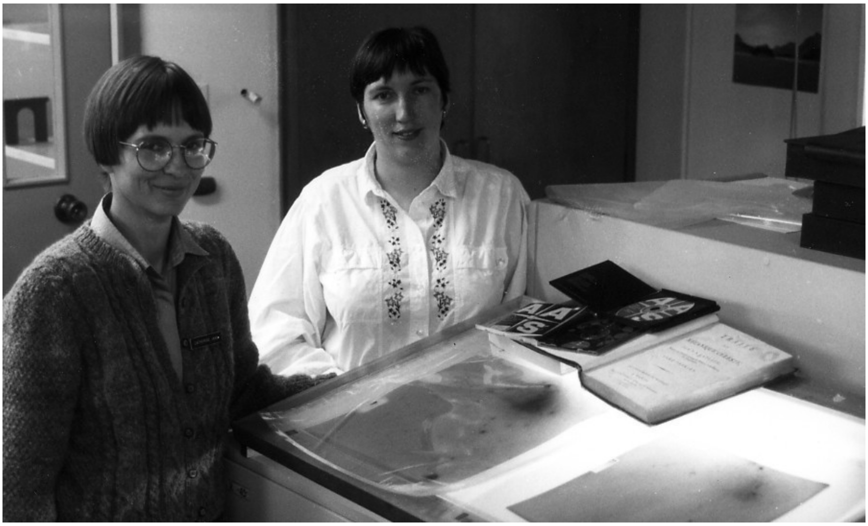
Astronomy-related research is undertaken, or has been, in many other of the University's departments, including the Departments of Chemistry, Electrical & Electronic Engineering, Geology & Geological Sciences, Geography and Mathematics.

Readers interested in enrolling in the astronomy programme should in the first instance write to: The Department Secretary, Department of Physics & Astronomy, University of Canterbury, Private Bag 4800, Christchurch, New Zealand, Tel: (03) 364-2987, Extn. 7402, Fax: (03) 364-2469. The Department is on the World Wide Web at: `http://www.phys.canterbury.ac.nz/`

A first-year astronomy student examines a Celestron C-8 telescope during an afternoon laboratory session.

Third-year astronomy student Simon Bickerton familiarizes himself with the computer-controlled Celestron C-8 telescope installed on the roof of the Department of Physics & Astronomy. The telescope is used for senior undergraduate observing work. N.B. Simon is the great-great-grandson of Canterbury College's first professor, Alexander Bickerton (inset; see also page 8).

Former graduate students Kaylene Murdoch (left, PhD 1992) and Donna Ward (MSc 1992) take a break from analysing their observations with the Department's computers.



The library is an essential component of the astronomy programme and the University boasts the best modern astronomy collection in the country. Physical sciences librarians Catherine Jane (left) and Jenny Owens look up from examining two of the 2500 sky survey films of the southern sky. Also on the light table are some of the library's oldest and newest astronomy holdings: Laplace's Traité de mécanique céleste, *published in 1799, and CD-ROMs distributed with recent issues of the* Astronomical Journal *and the* Publications of the Astronomical Society of the Pacific.

Department of Physics & Astronomy—
Academic staff with interests in astronomy

Astronomy group

John B. Hearnshaw, MA (Cambridge), PhD (ANU), FRASNZ, FRSNZ
Professor

Stellar radial velocities. Spectroscopy of late-type stars. Active chromosphere stars.

Peter L. Cottrell BSc (Hons)(Adelaide), PhD (ANU)
Senior Lecturer

Spectroscopic and photometric analysis of chemically peculiar stars. Stellar pulsations.

William Tobin, MA (Cambridge), MS, PhD (Wisconsin), FRAS
Senior Lecturer

Early-type stars. The galactic halo. The Magellanic Clouds. CCD photometry. History of astronomy.

Others

W. Jack Baggaley, BSc (Hons), PhD (Sheffield), DSc (Canterbury), FRAS
Professor

Radar studies of meteors and interplanetary dust.

Noel A. Doughty, MSc (NZ), PhD (W Ontario)
Senior Lecturer

High-energy astrophysics and cosmology.

W. ('Bill') R. Moreau, BSE (Princeton), MS, PhD (Connecticut)
Senior Lecturer

Interface between general relativity and particle physics.

Observatory personnel at Mt John

Mike Clark, Senior Technical Officer
E. John A. Baker, Technical Officer
Alan C. Gilmore, BSc (VUW), FRASNZ, Senior Technician, Resident Superintendent
Pam M. Kilmartin, MA (Auckland), Senior Technician

Operation of the Observatory would be impossible without the support of many others in the Department in Christchurch as well as in the University's Registry and Computer Services and Works & Services Departments.

The Mount John University Observatory

William Tobin

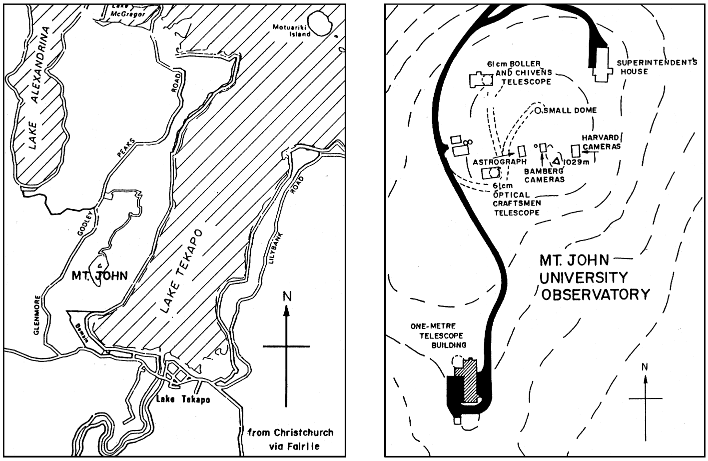
Take a tour of Mt John guided by the Observatory Director.

Here we are on an outcrop of sandstone rock—Mt John—rising 300 metres above the basin of the Mackenzie high country of South Canterbury. To the east and stretching north lies the watery finger of the Tekapo hydroelectric storage lake, made turquoise by the alluvial silt of the Godley River and Glacier. The Two Thumb Range provides a barrier to the Canterbury Plains beyond. To the north-west we see the green waters of the warmer, smaller Lake Alexandrina. Further to the west loom the Southern Alps, capped year-round with snow. On a clear day, you can see the summit of Aoraki (Mt Cook).

The mountains and lakes provide majestic surroundings for the Observatory, which is the most beautifully sited of all the many observatories that I know. The mountains also create a microclimate, and the weather at Mt John is neither that of the rainy West Coast, nor exactly that of the Canterbury Plains. Frequently I have driven from Christchurch under clouds that have melted into blue skies on entering the high country at Burke's Pass. While New Zealand has no sites for optical astronomy rivaling the world-class quality of those in northern Chile, Mt John is doubtless among the country's best.

Let me take you on a tour of the Observatory. The site map shows that there are two centres of activity. To the north, and on slightly higher ground, is the original Observatory, developed by the Universities of Canterbury and Pennsylvania (and later Florida) from the mid-1960s onwards. Two-hundred metres to the south are the buildings of the former satellite-tracking station which the US Air Force or civilian subcontractors built and operated from 1969 until 1983. High controversy attached to this American military presence. In 1972 protest culminated in a march up Mt John which is now mostly remembered for the fact that one demonstrator was bitten in a private part by a police dog, although others were more severely injured. When the tracking station closed down, the University of Canterbury was able to reacquire the lease on the land as well as a lease on the buildings, which now serve as an accommodation block and house the McLellan One-metre Telescope. Additional valuable legacies from the tracking station include the Observatory's sealed road, water supply, three-phase power, and a seemingly bottomless tank of diesel to fuel the snowplough.

We'll visit the McLellan Telescope first. We must be quiet, because last night's observers are asleep in the adjacent accommodation.



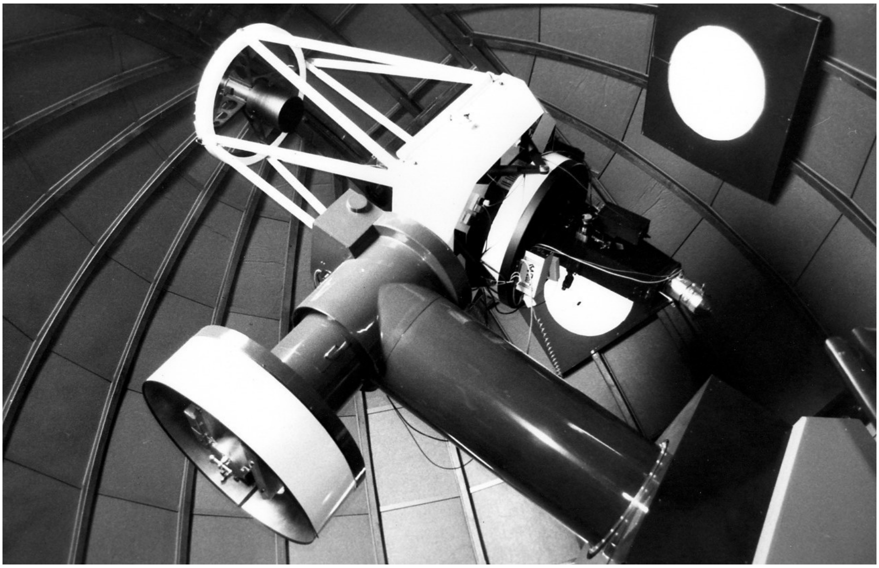
Location (left) and site (right) of the Mt John University Observatory.

We climb the stairs to the observing floor and discover the cream and green paintwork of the telescope. It is a *reflecting* telescope: the light is captured by mirrors, not lenses. It is the Observatory's and New Zealand's largest, and because of the great light grasp, it is the focus of our research activity. More light enables us to study fainter and more diverse types of stars—for almost all the research at Mt John concerns stars. Distant galaxies and cosmology require much bigger apertures.

The telescope has two mirrors. It's the first or *primary* mirror that is one metre in diameter. It is *concave*, like some shaving mirrors, and reflects and converges the beam onto a smaller, *secondary* mirror. The secondary is *convex*, like some wing mirrors, and returns the beam through a central hole in the primary to the *focal plane,* where the stars come into sharp focus behind the mirror cell. This is the conveniently-accessible *cassegrain* focus. A piece of film placed there will record an image, just as in a camera.

The telescope weighs 8 tonnes, but moves with precision as it tracks stars across the sky. Movable counterweights are adjusted so that the telescope is perfectly balanced and floating freely. Then only low-power motors are needed to drive the telescope. As the telescope moves, its cassegrain focus arcs up and down. Four jacks raise or lower the floor to follow suit.

A simple image of a galaxy may be very informative, but stars are so far away that they all appear as spots of light. Many facts about a star are hidden in the kaleidoscope of colours (or *wavelengths*) radiated in its light. Almost always, an instrument of some sort is bolted at the cassegrain



New Zealand's biggest: The McLellan One-metre Telescope. The large black box bolted at the cassegrain focus is the échelle spectrograph. Attached to its bottom end is the CCD detector, housed under vacuum in an octagonal cryostat. The circular screens affixed to the inside of the dome are used for calibrations.

focus to help decode the secrets of this luminous mixture. The big black box bolted there at the moment is one of our *spectrographs*, the échelle spectrograph. Like most astronomical instruments, it's not very inspiring from the outside. All the interesting optical components are hidden inside. What a spectrograph does is sort the starlight out into its component wavelengths, which can then be recorded. The study of spectra can tell many things about a star: its surface temperature and pressure, its detailed chemical composition, its instrinsic brightness, its velocity towards or away from us. The échelle spectrograph allows very detailed examination of a spectrum, but only for brighter stars. It's our most-used instrument, and is mounted on more than half the nights. We have another spectrograph in regular use. It's the recently-completed *Medium-Resolution Spectrograph*. It can be used on fainter stars, but fans the light into its component wavelengths relatively coarsely.

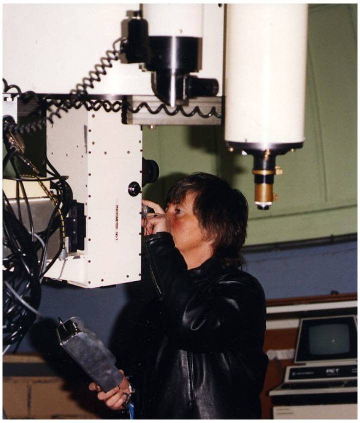
Another instrument we use is a *photometer*. It measures the strength of a star's light through different coloured filters. A hotter star emits proportionally more blue light, and so will appear brighter through a blue filter than a red one, while for a cool star the situation in reversed. With carefully selected filters it is possible to determine a star's surface temperature, how much its light has been dimmed by intervening interstellar dust, how luminous and far away it is, and even, in some cases, to obtain a rough estimate of its chemical composition.

Spectrographs and photometers both require some *detector* to record the light. In the past the detectors were photographic plates, and as we wander around the Observatory we'll notice a number of darkrooms. They are almost all superannuated! Astronomy has undergone a revolution in the last 15 years, thanks to solid-state electronic detectors. These semiconductor detectors are now close to perfect in the sense that they capture almost all the light, and add little perceptible degradation to the record. (This, incidentally, is why few big telescopes were built during the 1980s—better detectors were furnishing markedly improved observations. Now that there is little room for further improvements to detectors, the world's astronomers in their quest for more light are again busy building big telescopes—with 8- to 10-metre apertures.)

Mt John has one electronic detector in operation, a so-called Charge-Coupled Device, or CCD, and has just taken delivery of a second. Detectors are so crucial to modern astronomy that the article on page 26 is devoted to them. The CCD is inside this gold-coloured octagonal canister attached at the bottom of the échelle spectrograph, but we can use it with all the instruments. The canister holds liquid nitrogen which cools the chip to its chilly operating temperature of $-110°C$. The computer that controls the CCD is down below in the data room.

Let's wander back to the top of the hill and the old part of the Observatory. If we're lucky we may see the mottled plumage of a chukar hiding in the grass; John Baker, one of the Observatory technicians, feeds them

Electronic detectors require sophisticated control computers. Most of a night's observing is now done not from the dome, but from the crowded data room.



Pam Kilmartin, technician-observer at Mt John, adjusts a photometer on the 0.6-m Boller & Chivens Telescope.

through the winter. There has recently been a drop of poisoned carrots, but at other times it can require very little luck to see a rabbit.

One of the first instruments to arrive on Mt John was this astrograph. Professional telescopes often have very small fields of view—smaller than the angular extent of the Moon—but the astrograph is a special form of telescope designed for photographing wide areas of the night sky. In the early seventies the southern sky had not been systematically mapped photographically to faint limits, so this astrograph was used to complete the southernmost cap of a survey of the entire sky which had been begun in the northern hemisphere by the Lick Observatory in California. For a while the *Canterbury Sky Atlas*, published in 1972, was the only available photographic map of the deep southern sky, but since the 1980s it has been surpassed by much deeper and more detailed photographic surveys made with more powerful wide-angle telescopes in Australia and Chile.

The luminous flux from the Sun is constant, at least on human time scales, but this is not the case for all stars. Many are *variable*, and this circumstance is a happy one for the astrophysicist because the variations provide additional clues to the nature of the stars and their internal structure. But before you can study variable stars, you must find them. For a decade the Remeis Observatory (Bamberg, Germany) operated a search from Mt John for variable stars in the southern Milky Way. The cameras have not been used for twenty years now, but their building's darkroom did serve for developing the plates from another sky patrol. For almost a century the Harvard College Observatory in the US has regularly been photographing the northern sky. The plates are archived at Harvard, and have proved very useful in identifying optical counterparts to high-energy phenomena such as X-ray bursts detected from satellites. At various times

The 0.6-m Optical Craftsmen Telescope (left) and Cook astrograph (right) in the early 1970s. The astrograph was used to produce the Canterbury Sky Atlas *by Doughty, Shane & Wood, published in 1972. Rebuilding the Optical Craftsmen Telescope in the late 1970s showed that the Department of Physics contained the expertise needed to build a 1-metre telescope.*

the patrol has been extended to southern skies, first from Peru, later from South Africa, and finally from Mt John. Unfortunately the southern patrol was curtailed in 1990 when funding was withdrawn as a result of the US budgetary blow-out.

Over in this building we have a 0.6-metre telescope. It was the first big reflecting telescope on site in 1970. It is the Optical Craftsmen Telescope and is used exclusively for photometry. It was the rebuilding of this telecope in the late 1970s that gave our technical staff the experience and confidence to tackle building the McLellan Telescope.

We have another 0.6-metre telescope, built by the Boller & Chivens company in California, and installed in 1975. It's a very nice telescope to use because it's human sized. True, you sometimes have to climb ladders to get to the finder telescope, and this is never pleasant in the dark, but you don't have to go very high. You can move the 'B&C' quickly and easily from one part of the sky to another, and it has crisp optics. At present some of the B&C telescope time has been allocated to the University of Auckland in exchange for computerization of the telescope control. Otherwise the

University of Canterbury **Department of Physics and Astronomy**

MT JOHN UNIVERSITY OBSERVATORY

Schedule for: 1996 MAY (Revised April 19)

Date (U.T.)	**Moon**	**1m McLellan Telescope**	**0.6m B&C Telescope**	**0.6m O.C. Telescope**	**Astro-graph**	**Remarks**
1 Wed		│ WATSON	⇑ YOCK	│ BUDDING		Graduation
2 Thur		│ (CONT.)	│ MOA	⇓ (cont.)		
3 Fri	FULL	│ échelle+ CCD	│	⇑ KILMARTIN/		Graduation
4 Sat		│	│	│ GILMORE		
5 Sun		⇓	│	│ Service		
6 Mon		⇑ HEARNSHAW	│	│ photometry		
7 Tues		│ f/8 + FFE	│	│		
8 Wed		│ VISUAL × grating	│	│		
9 Thur		⇓ Late ty. ⋆ RVs	│	│		
10 Fri	LAST	⇑ CUMMINGS	│	│		RASNZ conf
11 Sat		│ f/8 + FFE	│	│		RASNZ conf
12 Sun		│ VISUAL × grating	│	│		RASNZ visit
13 Mon		│ K, M ⋆ RVs	│	│		Term 2 begins
14 Tues		⇓	│	│		
15 Wed		⇑ KERSHAW f/13.5	│	│	†	
16 Thur		⇓ Tests f/8	│	│		
17 Fri	NEW	⇑ SULLIVAN	│	│		
18 Sat		│ f/13.5	│	│		
19 Sun		│ 2-channel phot.	│	│		
20 Mon		│ Pulsating WD	│	│		
21 Tues		│ L19-2	│	│		
22 Wed		⇓	│	│		
23 Thur		⇑ WATSON	⇓	│		
24 Fri		│ f/13.5	⇑ ASTR381	│ ASTR381		ASTR381 visit
25 Sat	FIRST	│ MRS + CCD	⇓ ASTR381	│ ASTR381		ASTR381 visit
26 Sun		│ 600 l/mm × grating		│		
27 Mon		│ Active chromospheres	⇑ CLARK	│		
28 Tues		⇓	│ Tests of	│		
29 Wed		⇑ J.SKULJAN	│ new CCD	│		
30 Thur		│ f/8	│ system	│		
31 Fri		│ FFE + CCD	│ Top Hat, MRS?	│		

† Homes/Gilmore to use astrograph at any convenient time.

Head of Department:	Dr R.W.G. Syme, Tel.: (03) 364 2764
MJUO Director:	Dr W. Tobin, Dept of Physics and Astronomy, University of Canterbury, Private Bag 4800, Christchurch, New Zealand Tel +64 (3) 364 2531 Fax +64 (3) 364 2469 Email(internet):w.tobin@csc.canterbury.ac.nz
MJUO Superintendent:	Mr A. C. Gilmore, Tel.: (03) 680 6813
MJUO observers:	Fax & tel (rings during music): (03) 680 6507
Auckland observers:	(03) 680 6534 (B&C office)
MJUO location:	170° 27.9′ E, 43° 59.2′ S
Postal address:	Mt John University Observatory, P.O. Box 56, Lake Tekapo, New Zealand.

telescope is mostly used for photometry.

Who uses these telescopes, and for what? This telescope schedule for May 1996 will give some answers. The Observatory is one of the University of Canterbury's field stations. It is primarily used by the University's staff and graduate students, who make a written case every three months requesting the telescope time they would like to be allocated in the coming quarter. It is then my unenviable task as Observatory Director[1] to try to accommodate everyone's requirements. The success of the McLellan Telescope is indicated by the fact that requests have recently been outnumbering available nights by 50 per cent. This is a consequence of the healthy number of graduate students attracted to Canterbury's astronomy programme.

The thrust of research at Mt John since its inception has been the study of variable stars. Such studies need long series of observations. Big observatories overseas usually have as their mission the provision of telescope time to a large number of astronomers for a wide variety of projects. Committees decide who gets time, and are usually reluctant to award the large number of nights over long intervals needed for variable-star work. This leaves a niche for variable-star astrophysics at university observatories like Mt John, which are responsible only to their parent institution. Looking at the May schedule, all the allocations on the McLellan Telescope are to do with stellar variability except for the one to Kershaw, which is for engineering tests, and the one to Skuljan, which concerns the motions of stars near the Sun. We also run programmes in tandem with other observatories in order to obtain continuous, uninterrupted observations, which are important for rapidly-varying phenomena. As night sweeps westwards, at least one observatory is always in darkness. Our unique and isolated location fills a gap between observatories in Chile and Australia.

The Sun is nearing the western horizon and the streetlights are coming on in Tekapo. Notice how dim they seem from up here? Thanks to special lighting ordinances adopted by the Mackenzie District Council, the lights are of special construction or specially shielded to ensure that as little waste light as possible gets up into the sky where it could interfere with our research. We are very grateful to the Council and the residents of the Mackenzie for this support of our activities.

Well, while most people are preparing for an evening's relaxation, my working day has hardly begun. I must say goodbye and go and check over the equipment before making dinner and starting observations. I hope you enjoyed the tour.

Observatory resources are hard stretched fulfilling its research mission, so tours are only rarely given. To cater for those wishing to view the sky, the Department of Physics & Astronomy operates open nights at the Townsend Telescope in Christchurch (see page 83 for details).

[1] A chore that rotates around the academic staff.

Establishing the Mt John University Observatory

Frank M. Bateson

Frank was the 'man on the ground' who selected Mt John as the best available New Zealand site and then went on to build the Observatory. He tells the story.

The main requirements for a site for an astronomical research observatory are clarity of night skies and freedom from light pollution and the turbulence of the lower atmosphere. A mountain site is therefore desirable. There are many other considerations which have to be taken into account. A preliminary survey showed that suitable sites were in the South Island.

It was essential to record the meteorological conditions prevailing over each mountain site and to measure the parameters affecting astronomical observations. These factors enable the various sites to be compared with each other. This is termed site testing.

Site testing was carried out in Marlborough, Nelson, South Canterbury and Central Otago during a two and a half year period from February 1961. It was funded by the National Science Foundation, Washington, through the University of Pennsylvania, as they were interested in a joint venture with the University of Canterbury.

The final report on the NZ site testing recommended Mt John as the preferred mountain. The universities accepted the recommendation, announcing their decision in a press release on 30 July 1963. There was on Mt John, at this stage, a meteorological enclosure, a small musterers' caravan as living quarters, and a sliding-roof building housing my 20-cm refracting telescope with which the final testing had been done. Dr Horace Babcock, Director of Mt Wilson and Palomar Observatories, had also tested Mt John in his search for a site for the very large Carnegie southern-hemisphere telescope. His findings were that whilst Mt John was suitable for moderate size telescopes, it was not desirable for very large instruments on account of New Zealand's changeable climate.

The caravan had been lent by Mr & Mrs John Scott of Godley Peaks Station, and was returned to them. I then lived in a cottage at Lake Tekapo, climbing the mountain several times daily whilst planning developments. Both universities made it plain that they had no money for building, and it was up to me to obtain funds. Pennsylvania undertook to ship certain instruments from the United States of America. They also wanted to send graduate students to obtain data on southern stars.

The story of how funds were obtained has been told in my autobiographical *Paradise Beckons* (see page 123). It was obvious that the first building would have to be some form of living quarters. This would enable me

An aerial view of Mt John in 1975 looking south-east. Lake Tekapo and Tekapo village are in the distance. When this photograph was taken, the southern part of the mountain top was occupied a US satellite-tracking station (extreme right), but it now accommodates the McLellan One-metre Telescope.

to live on the mountain in order to provide protection for valuable instruments. It would also enable graduate students, when they arrived from the States, to live and work on the mountain. The second building was a cylindrical concrete structure with a rotating roof. This was to house my 40-cm reflecting telescope, made available to the graduates so they could obtain data on southern stars. Power was supplied through an electrical cable installed up the mountain.

The next building I designed was a large, well-equipped house. This was essential to provide adequate accommodation for whoever would be permanently stationed on the mountain. Finally a building was erected to house the Cook Astrographic Camera from Pennsylvania. This instrument was used to take the photographs of the southern sky that resulted in the *Canterbury Sky Atlas.*

There was tremendous public support and widespread media attention throughout the harsh rigours of site testing. This interest continued as Mt John was established, with valuable assistance from the Mackenzie County Council, the station owners of the district, service clubs, and the citizens of Timaru and surrounding districts. The determination of Professor Brad Wood to have a joint NZ–US observatory enabled me to turn my dreams into reality by laying the foundations that would enable keen young New Zealanders to study and qualify in astronomy.[1]

[1]The University of Canterbury has awarded 26 MSc degrees and 7 PhD degrees in optical astronomy since the founding of Mt John.

Electronic detectors

William Tobin

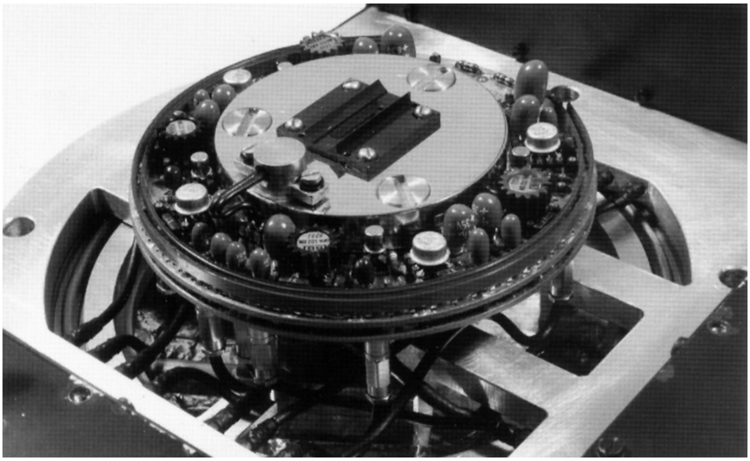
Electronic detectors have revolutionized optical astronomy, and Mt John has been part of the revolution. William tells the story.

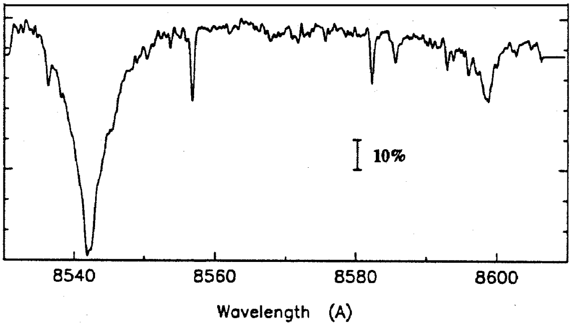
Although the first practical photographic process dates back to 1839, it was not until the 1880s that photography began to make a significant impact on astronomy. A first advantage was that with a time exposure, photography could add up the light from faint objects, rendering the invisible visible. A particularly spectacular example of this concerned the Pleiades star cluster. Extensive eyeball scrutiny by hundreds of astronomers had never found anything other than stars. But the first photograph showed a completely unsuspected haze around Maïa and others of the stars. We now know that this luminous veil, or nebula, is due to the presence of smoke-particle sized graphite grains in the space around the stars of the Pleiades. The grains glow by scattering light, just as dust particles glint in a sunbeam. Further advantages of photography were that thousands of stars could be recorded simultaneously, and that the photograph could later be studied at leisure in a warm office during the day (or a cloudy night). With the human eye as detector, measurements could only be made star by star on clear nights in a chilly dome.

Photography greatly extended human knowledge of the cosmos, revealing, for example, a large expanding universe filled with galaxies. But photography is wasteful of light. Typically only about one per cent of the light that falls on an emulsion results in blackening. It is also subject to a host of annoying defects, such as uneven agitation of the developer, which makes it difficult to make highly accurate measurements of the intensity of a star's light from photographs.

After World War II it became possible to make high-quality measurements of stellar brightness using devices called photomultiplier tubes. But photomultipliers have no imaging capability and can only easily measure one star, or one element of a spectrum, at a time.

The semiconductor revolution began to change all this in the 1970s. Everyone is now familiar with the characteristic red or green glow from the light-emitting diodes, or LEDs, which are scattered all over the control panels of CD players and other electronic gadgets. When electronic charge passes through an LED, it emits photons, the particles of light. But semiconductor diodes also work in reverse. If photons are shone on a diode, charge will pass. The amount of charge is proportional to the number of photons, and can be used as a measure of luminous intensity.





The Mt John Linear Diode Array detector. Upper: Part of the LDA camera-head electronics. The LDA sensor nestles behind the matt black faceplate. Lower: An LDA spectrum. Semiconductor detectors are sensitive into the near infrared. Here the strong absorption at 8542 Å (or 854.2 nm) is produced by singly-ionized calcium atoms in the southern Cepheid variable β Doradus.

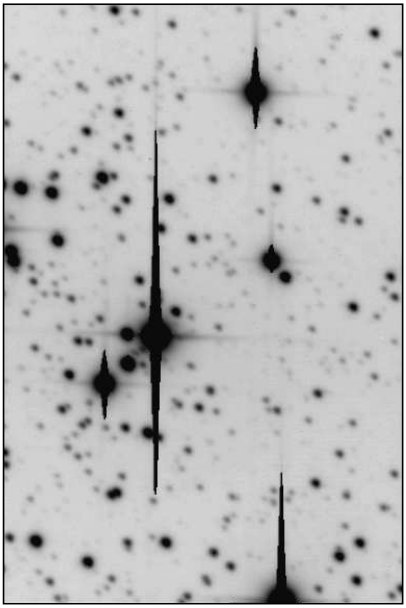
The Reticon Corporation in the United States was an early manufacturer of *linear diode arrays* (LDAs). Reticon made silicon chips with typically 1872 diodes ranged side-by-side in a straight line. The signal from each diode could be recorded individually via appropriate electronics.

In the early 1980s the University of Canterbury's Department of Electrical and Electronic Engineering began experimenting with an LDA. From this beginning astronomy doctoral student Phillip MacQueen in the Department of Physics developed a state-of-the-art LDA detector system for use at Mt John. This was no mean feat. The electronics had to be very carefully designed so as to add as little as possible to the signals in the way of extra noise and uncertainty. Unfortunately, the fact that a diode is warm can also cause charge to migrate across its junction. To minimize this cause of signal degradation, the LDA chip and electronics must be cooled far below freezing point using liquid nitrogen. This in turn means that the chip and electronics must be run under high vacuum in order to reduce heat transfer and prevent condensation.

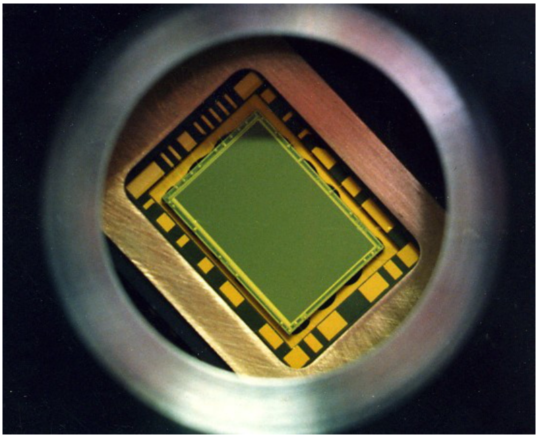
All this complication is well worth it. An electronic detector is perhaps 50 times more efficient in its use of photons than a photographic emulsion, and can measure intensities to sub-percent accuracy.

An LDA is a one-dimensional, one-line detector. This means it is hardly any better than a photomultiplier for two-dimensional imaging. However, many astronomical observations involve the recording of spectra. Spectra are one-dimensional and an LDA is ideally suited to recording them. MacQueen's LDA system was used with the échelle spectrograph at Mt John from 1986 until 1991.

In the early 1980s two-dimensional electronic detectors became available. These are the charge-coupled devices, or CCDs. CCDs are now often the detectors in home-video cameras, but for use at the lowest light levels they too need to be operated cooled with liquid nitrogen and under



The central part of Herschel's Jewel Box *recorded by the Mt John CCD system and 0.6-m Boller & Chivens telescope. The Jewel Box (also known as the κ Crucis cluster) is a well-known southern cluster of stars lying close to the direction to the Southern Cross, and about 7500 light years distant. The region shown spans about 4×6 minutes of arc. The faint horizontal streaks radiating from the brightest stars are due to light reflected from the struts that hold the telescope's secondary mirror. The strong vertical streaks occur when the charge-holding capacity of individual CCD pixels is exceeded. Compare with the photograph of κ Crucis on page 83.*



The detector chip of the CCD system that has been in use at Mt John since 1989. The chip comprises 384×576 sensitive elements, or pixels, *and fulfills the rôle of an electronic piece of film.*

vacuum.

CCDs have a cardinal advantage in addition to their imaging capability. They add far less extra noise to their signals than even an LDA. In consequence even fainter signals can be detected, just as a high-quality radio tuner can pick up weaker stations than a cheap transistor. The power of CCDs is illustrated by the following fact. With a CCD and the McLellan Telescope, projects can be undertaken at Mt John which, with photography, would have required the 5-metre telescope on Mt Palomar.

Though the LDA project produced a very-employable PhD graduate, it was a slow way to acquire an LDA detector system. This experience, and the crucial need to get the greatest astrophysical return from the investment in telescopes, instruments and personnel at Mt John, meant that the only sensible way to acquire a CCD system for the Observatory was to buy one from a commercial supplier. The Department, the University, the Lottery Grants Board and the University Grants Committee provided funding, and in 1988 a system was purchased from Photometrics Ltd of Tucson, Arizona.

Even with a commercial system, several years' effort was necessary before it was a fully operational, well-understood detector for astrophysical research. Important practical issues with electronic detectors are data rate and reduction facilities. 'Reduction facilities' are the computers and software needed to process the raw signals delivered by the detector into wavelength-calibrated spectra or precise measures of stellar brightness.

With 1872 elements, linear geometry and use only in spectroscopy, the LDA reductions could be performed on the detector control computer using relatively simple software, and many nights' results could be stored on a single diskette.

With almost a quarter of a million picture elements (or 'pixels') per

The data produced by electronic detectors are not immediately publishable. The raw digital numbers need calibration and spectra or flux levels need to be extracted. Sophisticated computer programs are needed for these reductions *which are done on the University's computers in Christchurch.* MIDAS *from the European Southern Observatory and* FIGARO *from the Anglo-Australian Observatory are the the two software systems that are mostly used. Here former students Dave Frame (MSc 1993) and Karen Pollard (PhD 1994) are hard at work reducing data.*

image, the Photometrics CCD system would have required many dozens of diskettes to store a single night's observations. Image display capability and complex software were needed for reductions. Image display is now standard on personal computers, but in 1988 it required expensive, custom-designed equipment.

Magnetic tape was used for the storage of CCD data, and reduction facilities were set up only in the Department in Christchurch. For reduction software, MIDAS (the Munich Image Data Analysis System from the European Southern Observatory) was installed on VAX/VMS computers in Christchurch. Later, FIGARO, a package from the Anglo-Australian Observatory, was also made available on the University's central Unix computers. MIDAS, for example, can reduce simple spectra as well as the multiple, inclined, cross-dispersed spectra from our échelle spectrograph, and can extract individual stellar fluxes from images of crowded star fields. It also has a spreadsheet-like data structure from which spectra and graphs can be plotted and has numerous tools for analysis.

The Photometrics CCD was tested out on the Observatory's 0.6-metre Boller & Chivens Telescope, but since 1991 it has been the principal detector used with the McLellan Telescope. A special photometer head has been built for photometry of stars in the Magellanic Clouds and the CCD has also been interfaced to all of the Observatory's spectrographs.

This CCD system has served us well, but is coming to the end of its life. Last year funding was obtained from the Department, the University and the Lottery Grants Board for a replacement system which was delivered in April 1996. It is currently undergoing tests and software improvements in Christchurch, and on present expectations should be installed at Mt John towards the end of the year. This CCD has four times more sensitive area, or over one million pixels, and will place new and heavy demands on reduction facilities. CD-ROMs will be used for data recording.

The technical support of electronic detectors is a heavy burden, but without professional-grade CCDs research at Mt John would not be internationally competitive. All users of the Observatory are very grateful for the financial and other support which has made their acquisition possible.

Ross Ritchie (centre), head of the Electronics Workshop in the Department of Physics & Astronomy, points out the large chip inside the new CCD detector system received in April 1996 (1024×1024-pixels). Looking on are MSc student Stephen Persson (left) and electronics technician Geoff Graham.

Unique astronomical programmes at Mt John: long-term photometry and spectroscopy

Peter Cottrell

Peter, who is Senior Lecturer in Astronomy at the University of Canterbury, explains how to get the best out of a small observatory.

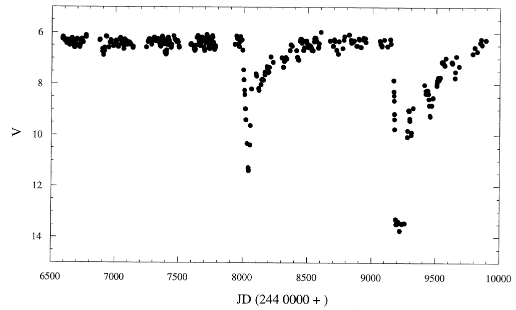
Apart from its unique geographical location (in both longitude and latitude), Mt John University Observatory has a novel way in which it operates some of its observing programmes, enabling longer-term projects to be carried out. Long-term projects are often not encouraged or supported in astronomy as scientific researchers, and their funding agencies, want to get 'instant' results from one or a few nights' observations. The longer projects are sometimes labelled as being simply 'stamp-collecting' (a term Ernest Rutherford used to describe all aspects of science apart from physics!) and not 'real' science. In this brief article I hope that I can give you some examples of the need for both long-term photometric monitoring of variable stars and detailed long-term spectroscopic observations.

Many stars in the universe change their brightness in various ways (astronomers call them variable stars) and some of these are not particularly regular in that variability. Even the more regular variables yield some important clues for an understanding of the structure of stars, especially when detailed spectroscopic observations are made over time intervals
from months to years.

The Mt John University Observatory long-term observing programme has involved a symbiotic relation between the facilities available and the type of research programmes which we wanted to undertake. We have developed a modest observatory by international standing, but have well-equipped and well-calibrated instruments on small telescopes, and can gain regular access to these telescopes by employing resident technician-observers to assist us in doing parts of the scientific research.

To gain recognition for this type of research—and to acquit it from the accusation of stamp collecting—it is imperative that its focus must be to provide observational tests of existing scientific models or to prompt specific developments in the modelling process.

The types of objects which we have chosen for these long-term programmes are generally stars in the later stages of their evolution, prior to becoming one of the cosmic remnants—a white dwarf, neutron star or black hole. (The final endpoint for a star depends upon its mass at the end of the



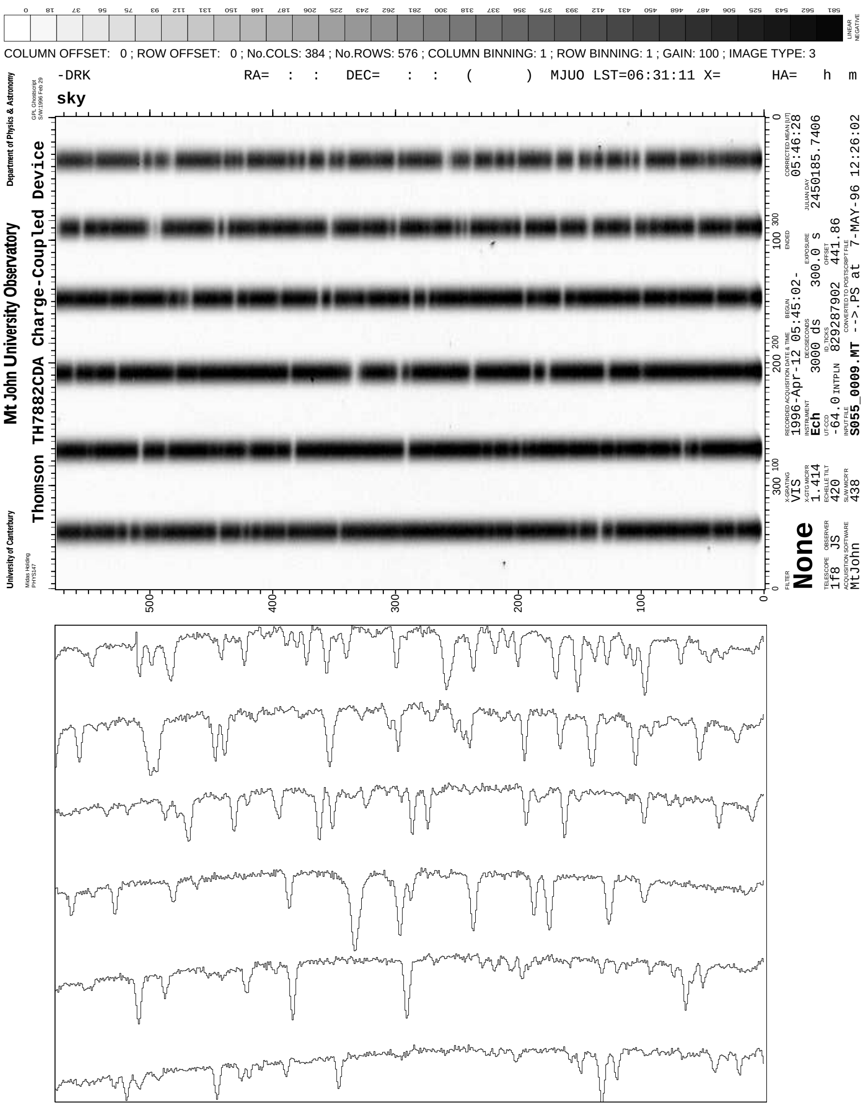
The change in light output for RY Sagittarii as a function of the Julian Date, which is a day count used by astronomers. These data extend from 1986 (JD 2 446 500) through to 1995 (JD 2 450 000). At its maximum brightness the star is visible to the naked eye. However, twice in this 10-year interval the star has dimmed by more than 5 magnitudes (a factor of 100 in brightness) due to the formation of obscuring dust near its surface.

nuclear burning stage of its evolution.) Some of the evolutionary phases of a star are relatively rapid and so changes in the stars can sometimes be seen in human lifetimes—an unusual occurrence in astronomy where timescales are usually measured in thousands of millions of years.

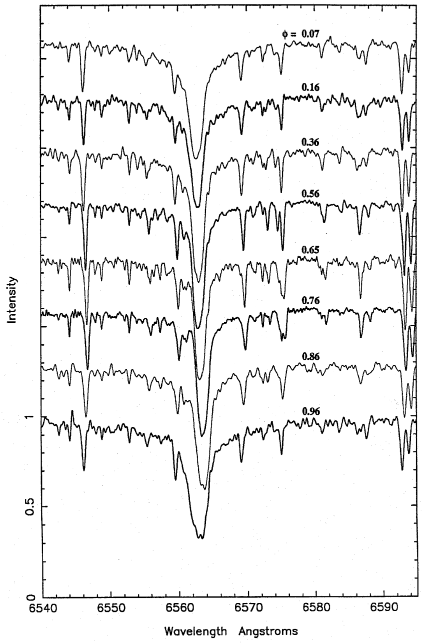
As examples, two projects will be considered; one photometric, the other spectroscopic.

The photometric project has now amassed more than ten years of data on a group of quite peculiar stars known after the first star of its type to be recognized, R Coronae Borealis. These variable stars are one of the more extreme types of star in the universe. Only about 40 have been identified in our Galaxy (out of approximately one hundred thousand million stars). Their strangeness is two-fold. They are composed of about 90% helium, 9% carbon and 1% of all the other elements (whereas most stars in the universe have 90% hydrogen, 9% helium and 1% everything else), and they occasionally undergo a phase where they dim over a period of several weeks, and then recover to their normal brightness over several months to a year. An example of our data on the brightest southern member of this group, RY Sagittarii, is shown above. These data, especially those defining the dimming phase, have for the first time provided some quantitative information on the nature and evolution of the carbon-based material causing the obscuration of these stars.

The spectroscopic project involves observations (see figure on page 35) of Cepheid variables, a type of regularly pulsating star which changes its brightness as a result of changes in its size and surface temperature. Cepheids are one type of object that is used to determine the actual size and fate of the universe, which has been one of the quests of astronomers



Upper: The appearance of a raw CCD échelle spectrogram. The échelle spectrograph disperses the light in two dimensions. Here 6 orders *are shown. Each order is a high-definition spectrum of a small wavelength range. The full range of wavelengths is 'tiled' by adjacent orders. Lower: reduction software is used to extract intensity plots of each order. These are the spectra. You can see that each tracing corresponds to an order in the CCD image. The reduction software can also be used to calibrate the plots in terms of wavelength and to correct for various instrumental effects.*



A stack of spectroscopic observations of the binary Cepheid, S Muscae, through its pulsational cycle. The strongest absorption is a Balmer line of hydrogen. The pulsating motion of the star is deduced from the change in wavelength of the Balmer line and other spectral lines that are formed in the star's atmosphere. The change in shape of the Balmer line can also be analysed in terms of dynamic motions in the star's outer layers.

and others for many centuries. Cepheids are intrinsically very bright and can therefore be seen at great distances, enabling them to be measured in many distant galaxies. Determining details of their fundamental properties, for example their mass, is important for testing theories of stellar evolution, upon which so much of our understanding of the structure of stars depends. Some of the Cepheids that we are observing from Mt John are in binary systems—cases where two stars orbit about their common centre of mass. These data have been compiled over a period of up to eight years and are used to determine the shape of the stars' orbits. Working with collaborators who obtain additional observations with the Hubble Space Telescope, it is then possible to determine the mass of the Cepheid in each binary, and hence provide the necessary tests of present theories of stellar evolution as well as consolidation of the scientific basis for the observational programme.

Sizing–up stars in the Magellanic Clouds

William Tobin

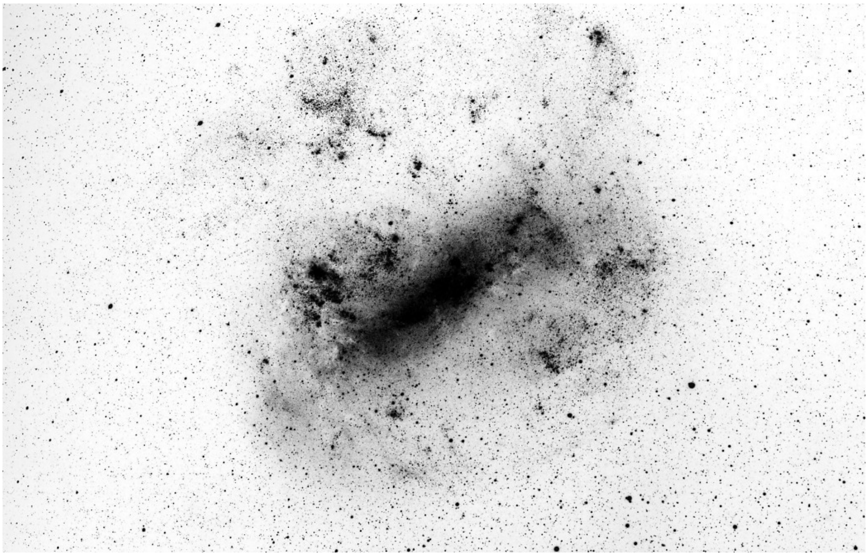
The Magellanic Clouds offer special opportunities for observational tests of our theories of stellar structure and evolution.

Tioreore and Tikatakata are but two of the dozen or so Māori names for the Large and Small Magellanic Clouds, and this multiplicity of names indicates the Clouds' prominence in the pre-European firmament. Easily visible to the naked eye on a clear, moonless night, the smudge-like Magellanic Clouds are also of prime scientific importance. These two irregular-shaped galaxies are each collections of several thousand million stars. Although light from the Clouds takes 150-200 000 years to reach us, the Clouds are cosmically only a stone's throw away. They are among the nearest galaxies outside the Milky Way, the great pinwheel galaxy in which our Sun is located. Conditions in the Clouds differ from those in the Milky Way; in particular, the Clouds are weaker in heavier elements. In consequence, the nature of stars in the Magellanic Clouds and their life history are without doubt different from those of their cousins in our Galaxy. These differences must be searched out observationally and then understood theoretically. That differences do exist was illustrated dramatically in February 1987 when a massive star in the Large Magellanic Cloud ended its life in the ten-thousand-fold brightening of a supernova explosion. This was the first naked-eye supernova in almost 400 years. The expectation was that supernovae would only be produced by red stars, but it transpired that the progenitor of the 1987 outburst was a blue star. This fact is now explained by differences in chemical composition.

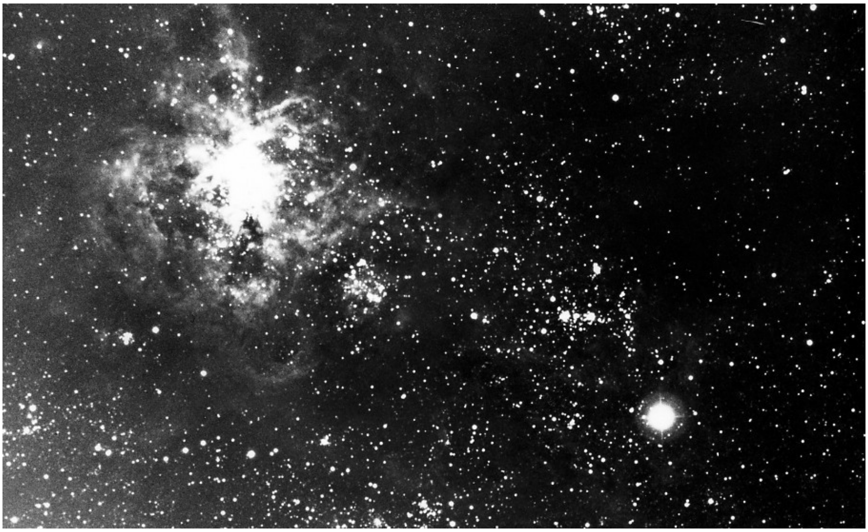
When it comes to observing the Clouds, New Zealand astronomers have an advantage over competitors in Australia, Chile and South Africa. This is because New Zealand's more southerly latitude places the Clouds at a higher elevation in the sky. They can be studied year round and the Earth's atmosphere dims their light less.

Astronomy advances through a continual interplay between observation and theory. Theoretical understanding of stellar structure and evolution has to be checked, and as necessary modified, by comparison of theoretical stars with real ones. Our observational knowledge of the diameters, masses and other vital statistics of stars derives almost exclusively from a class of variable star known as eclipsing binaries.

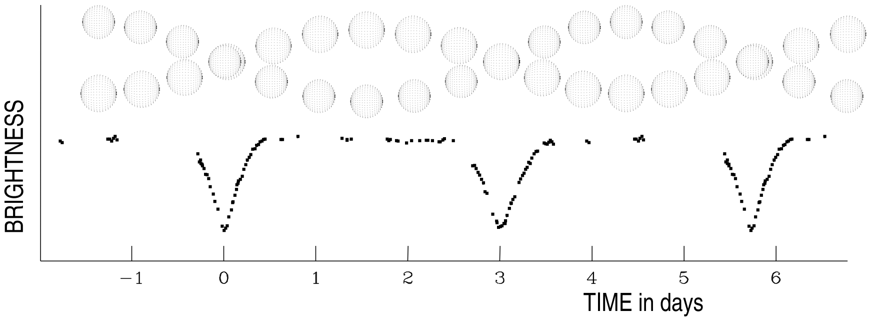
In these systems, as in any binary star, two stars orbit each other under their mutual gravitational attraction. The stars are too far away to be resolved individually: all that can be observed is their aggregate brightness.



The Large Magellanic Cloud (LMC) as it appears in the Canterbury Sky Atlas. *The photograph shows an area about 11.5°×7°. The LMC is some 200 000 light years away.*



The first supernova visible to the naked eye in almost 400 years occured when a star in the LMC was seen to explode on 24 February 1987. The supernova shines brightly near the giant Tarantula Nebula in this photograph taken 12 days later with the Boller & Chivens Telescope at Mt John. About 0.6°×0.4° is shown. Can you spot the Tarantula Nebula in the Canterbury Sky Atlas *photograph?*



Mt John photometry of HV 2274 in the Large Magellanic Cloud with a schematic illustration of how the eclipses arise. Close scrutiny reveals that HV 2274's eclipses are of unequal width and unevenly spaced, showing that the orbits of the component stars are not circular but elliptical. A full orbit takes almost 6 days.

By chance, however, the plane of an eclipsing binary's orbit lies very close to our line of sight to the system. As seen from Earth, the total light dims *twice* per orbit as first one star moves in front of the other, blocking its light, and then is itself eclipsed about half an orbit later.

It is possible to understand how eclipsing binaries can yield fundamental properties of their component stars without any recourse to mathematical details. The classical observational data for an eclipsing binary are its light and velocity curves—plots of how the total brightness and the velocities of the individual stars vary during the orbital cycle, or period. The light curve is obtained with a photometer of some sort; the velocity curves, one for each component, derive from spectroscopy and the Doppler-Fizeau effect. This effect is the bunching together, or spreading out of waves when a source of wave motion approaches or recedes from an observer. Police use the Doppler-Fizeau effect in speed radars. Astronomers employ it to measure the speeds of stars with respect to the Earth. For an eclipsing binary the velocities are obtained during the out-of-eclipse parts of the orbit when the difference of speeds is greatest, with one star approaching the observer and the other retreating.

From the light curve it is possible to determine the relative dimensions of the two stars and their orbit. At the beginning and end of each eclipse, as illustrated above, the projected discs of the two stars are just touching and the projected separation of the stars is just the sum of their radii. The eclipse duration as a fraction of the orbital period is thus related to the relative sizes of the orbit and the sum of the stellar radii.

Likewise, the duration of the deepest part of the eclipse is related to the difference in stellar radii as a fraction of the orbital separation. From these sums and differences the individual stellar dimensions (relative to the orbital size) can be calculated.

These relative dimensions can be made absolute (i.e. put into solar radii, metres or other absolute units) via the velocity curve, since measurements of how fast a star moves, and for how long, give the distance travelled. This is the circumference of the orbit, from which its linear size easily follows, and then those of the stars themselves.

Gravity keeps the Earth in its orbit around the Sun, and how long it takes the Earth to complete an orbit (i.e. the duration of the year) depends on the size of the orbit (i.e. the distance between the Earth and Sun) and the masses of the Earth and Sun. In the same way, the total mass of an eclipsing binary system can be derived from the period and size of its orbit. The individual stellar masses follow from the amplitudes of the two individual velocity curves, since the stars orbit about their common centre of gravity with velocities inversely proportional to their masses.

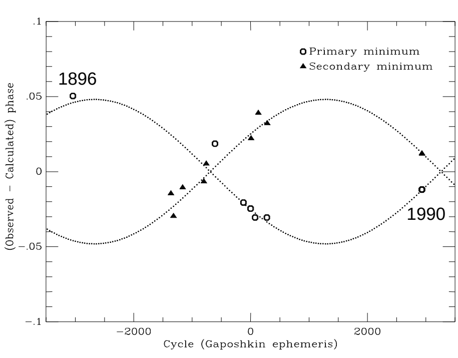
Finally, the depth of the eclipses are related to the surface temperatures of the stars or, equivalently, the relative power output of the two stars per square metre of surface. Since the surface area of each star can be calculated from its radius, the total power output, or absolute magnitude, can be determined. This can be compared with the binary's perceived brightness in the sky, or apparent magnitude, to determine the distance to the system. Very importantly, eclipsing binaries can be used as distance indicators to external galaxies.

Doctoral student John Pritchard loads liquid nitrogen into the CCD cryostat prior to a night spent observing eclipsing binaries in the Magellanic Clouds. The liquid nitrogen is at a temperature of −196°C. The cold reduces unwanted signals in the CCD chip.

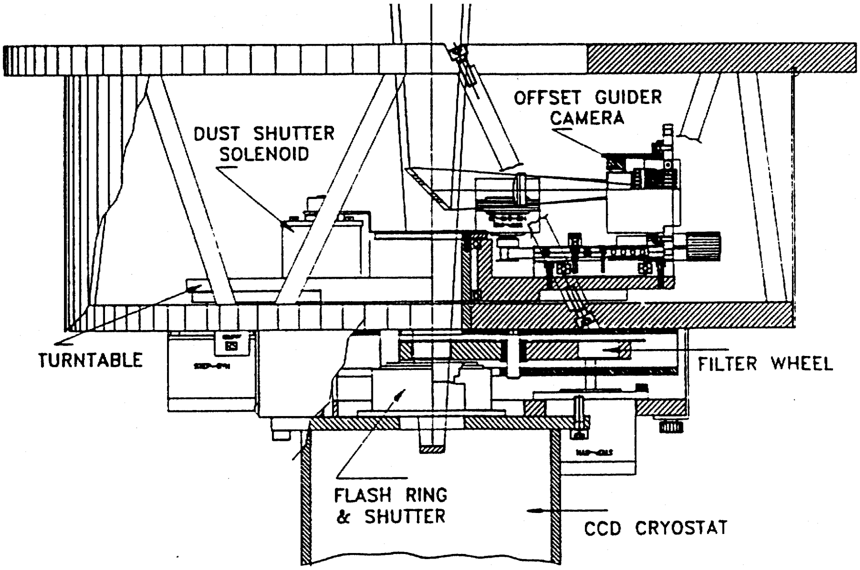
At Mt John, my students and I, as well as the Mt John technical staff who have assisted us, have been using the CCD detector for photometry of eclipsing binaries in the Magellanic Clouds.

A first observational campaign in 1990 taught us a lot about the problems inherent in using CCD detectors for the highest quality photometry. It also turned up some interesting systems. The stars in HV 12634 in the Large Magellanic Cloud appear too close together and thus too small or too hot to be like average main-sequence stars in the Milky Way. This may be because they are extremely young; it may also be because they are weak in heavy elements. HV 1761 in the Small Magellanic Cloud is a similar case, though less extreme.

However, the most interesting system observed in 1990 was HV 2274 in the Large Magellanic Cloud. The stars are relatively far apart in HV 2274 and their orbit is very close to exactly edge-on, which means it should ultimately be possible to determine very accurate parameters for the component stars. Furthermore, the widths of the two eclipses are unequal, as are the intervals between them. This is the hallmark of an elliptical rather than a circular orbit. Photographically-derived times of eclipse (one dating back to 1896) have been published for HV 2274 by workers at the Harvard College Observatory, and combined with the Mt John timings these show that the elliptical orbit is slowly altering its orientation in space with a period of about 123 years. This apsidal motion, as it is called, occurs because the stars are not spherical but are each elongated slightly by the gravitational pull of the other. The rate of apsidal motion depends on how the material is distributed within the individual stars, so with HV 2274 it should



HV 2274 turned out to be the first case of apsidal motion *discovered in a galaxy outside the Milky Way. Because tidal forces distort the stars, the orientation of the elliptical orbit slowly veers (apsidal motion), and the times of eclipses meander about their average values. Published photographic times of eclipses dating back to 1896 combined with the 1990 Mt John observations revealed that a complete rotation of the orbit takes 123±3 years. This will permit a probe of the internal distribution of mass once complementary velocity curves become available.*



An engineering drawing of the Mt John CCD photometer head. Key features are the offset-guider camera for correcting telescope tracking inaccuracies, and a computer-controlled filter wheel.

be possible to test theoretical predictions for the interior structure of the component stars, as well as for their exterior surfaces.

The 1990 observations were acquired with a simple observational technique and manually-changed filters for the various photometric bands. A proper CCD photometer head has now been constructed in the workshops of the Physics and Astronomy Department. The photometer head incorporates a computer-controlled filter wheel and an offset-guider camera. The signals from this camera are being used for automatic guiding of the McLellan One-metre Telescope. Along with various other improvements in the techniques of observation and reduction, the photometer head is resulting in much improved observational light curves (see page 77).

It is my philosophy that it is better to do a few things well rather than a larger number of things poorly. Consequently we are not ourselves applying for time on 4-metre class telescopes and spacecraft for the follow-up spectroscopy and ultraviolet measurements that are required before a definitive analysis can be made of the Mt John eclipsing binaries. Rather, we are leaving this to European and US collaborators. In New Zealand we are, we hope, both preparing the ground and reaping a harvest which will result in a more complete understanding of the nature of stars.

Some notes on spectroscopy at Mt John

John Hearnshaw

John is Professor of Astronomy. He recounts the story of spectroscopy at Mt John.

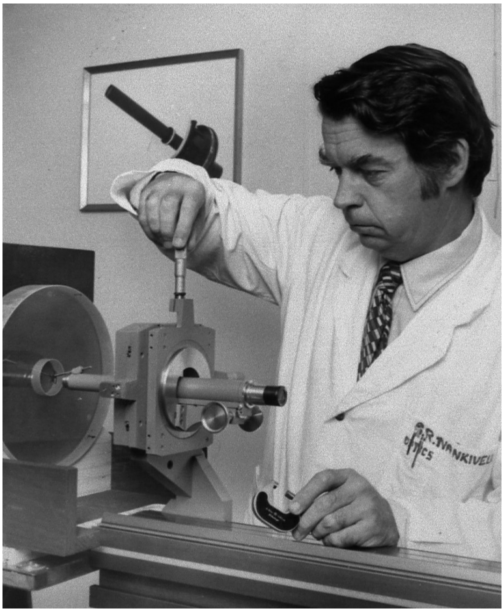
I came to the University of Canterbury in 1976 after being a post-doctoral fellow at the Harvard-Smithsonian Center for Astrophysics. Before that I had been a post-doc at the Paris Observatory. Having been at two of the world's largest research observatories, coming to Mt John was quite an abrupt change of environment. At that time we had the Optical Craftsmen telescope and the Boller & Chivens, both 61-cm reflectors. The former worked very poorly, mainly because of its periodic drive error and wobbly primary mirror. It was used for photoelectric photometry, but presented a major struggle to the most dedicated observers if reliable data, punched on-line onto cards, was to be obtained.

The Boller & Chivens telescope, installed in 1975, was quite a different story. It worked very nicely, but in the mid-1970s we had no instrumentation for it. Direct photography was an option, and the Department had built an image-tube camera for photographic photometry of quasars. This research was being done by Gerry Gilmore for his PhD research, but presented major obstacles because we had no easy way to calibrate the plates.

Mt John was never renowned for being a great photometric site, so with my background in stellar spectroscopy, it seemed logical that some change in direction would occur. In Australia, where I did my PhD, in France and in the United States I had been working on high-dispersion spectra of bright, cool stars, with the aim of analysing the spectra to obtain element abundances. This seemed a good sort of programme for Mt John, because spectroscopy does not require perfectly clear skies and for bright stars can tolerate a full Moon.

Traditionally the large coudé spectrograph had been the way to obtain such spectra, but at the Center for Astrophysics ('CfA'), Dr Dave Latham's group was among the pioneers of the cassegrain échelle spectrograph, a relatively light-weight and inexpensive option for obtaining high dispersion data. The first échelles had been used in astronomy in the early 1970s, and the CfA had designed and built not quite the first, but one of the most successful, which was in use on the 60-inch telescope at Mt Hopkins in Arizona. Another was used on the 60-inch at Harvard's Agassiz Station (now Oak Ridge Observatory) in Massachussetts.

When I came to New Zealand, Dave Latham very kindly made all the CfA spectrograph drawings available to Canterbury. Our workshops



Optician Garry Nankivell who figured the optics for the McLellan One-metre Telescope. He has also built the optics for most of the instruments at Mt John.

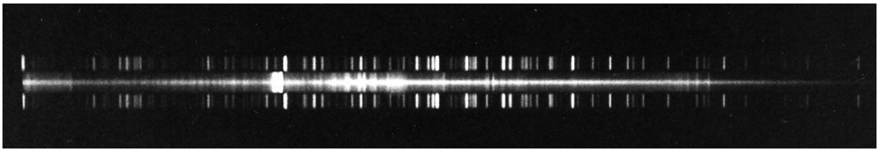
immediately set to work to construct an identical instrument. Graeme Kershaw and Morrie Poulton were employed full-time on this work. Construction began in 1975 even before I arrived, and a $13 000 UGC grant, obtained on my behalf by Prof. Brian Wybourne, was used for the purchase of parts such as the gratings and Zerodur for the mirrors. Garry Nankivell figured the optics, the start of a long association between him and Canterbury astronomy.

The échelle spectrograph was completed in March 1977, when it saw first light on the Boller & Chivens telescope. It weighed around 100 kg, so was a major load for the telescope to carry. As it happened, this instrument was not the first to be used for stellar spectroscopy in New Zealand. When in the United Staes I had spoken to Prof. Bradshaw Wood at the University of Florida in Gainesville. He had been the founder of Mt John in the 1960s, and as it happened, he offered Canterbury a medium-dispersion spectrograph of Boller & Chivens manufacture for our telescope. This spectrograph had become surplus to Florida's requirements, following the amalgamation of the astronomy departments at Florida and South Florida, so was an offer that Prof. Wood was happy to make. It was sent to New Zealand in the winter of 1976 on a five-year loan, and the first observations were made in September of that year. They were blue photographic spectra at 60 A/mm dispersion, and I observed what was just becoming a new topic, the so-called RS CVn or active chromosphere stars, of which very few confirmed cases in the southern hemisphere had at that time been identified. Some of my favourite stars from 1976 to 1980 were CF Tucanae, CF Octantis, GT Muscae, HR 1099 and HD 155555. Those with variable star names were given these names subsequently. Probably CF Tuc, with its obvious double H and K emission from two active stars in a close binary was my most favourite. That programme was the start of stellar spectroscopy in New Zealand. The very first spectrum ever recorded was a test exposure of the red giant star η Arae which I made in September 1976.

One of the problems of this early work was that all our spectra were recorded photographically. Photographic plates were notoriously inefficient, in spite of the complex gas hypersensitization techniques in which we invested. One promising avenue to improve speed and increase our limiting magnitude, which was about V=3 or 4 for the 2 Å/mm échelle and about 9 for the 60 Å/mm Florida spectrograph, was to use a single-stage image tube. I acquired an S20 electrostatically focussed Varo tube, and thereby obtained several magnitudes gain for the échelle, going to about V=6 in noisy spectra. With the Florida spectrograph, we also tried image tubes, but with only partial success because of flexure problems. Dr Bernie Bopp from Toledo, Ohio, worked on Hα spectra of southern RS CVn stars with me in 1981 and we did obtain some useful results in spite of the problems.

Meanwhile, the échelle spectrograph was giving some excellent results, and attracted Dr Krishna Desikachary from Canada as a post-doctoral fellow to Canterbury in 1979. We decided to undertake a detailed abundance analysis of the F-type supergiant star, Canopus, the second brightest star in the sky. The photographic spectra recorded were of superb quality, and went down to 310 nm near the atmospheric limit. We measured the abundances of 33 elements, extending this to 38 in 1988, one of the most extensive spectroscopic analyses ever undertaken for any star.

The ever-present problem with spectroscopy with small telescopes is recording enough photons. Larger telescopes provide one solution, and the 1-m McLellan telescope was one way we sought to overcome this problem. Another was a more efficient detector. In 1981 Phillip MacQueen began his PhD project to develop a liquid-nitrogen cooled diode array detector for the échelle. This programme was brought to fruition in 1986, thanks to Phillip's exceptional skill, after several years of considerable effort and many difficulties. It gave Mt John for the first time a modern solid-state electronic detector with which high signal-to-noise spectra of fainter stars could be recorded with the échelle spectrograph on the new 1-m telescope. The high-precision stellar radial-velocity programme at Mt John is just one among several that benefitted from Phillip MacQueen's detector in



The first observation with the McLellan Telescope was this photographic spectrum of Comet Halley recorded on 31 March 1986. It spans ultraviolet-blue wavelengths. The cometary spectrum, showing molecular emission bands, is flanked above and below by wavelength-calibration spectra from an arc lamp.

the late 1980s and early 1990s. Let me add that we now live in the age of the CCD, and we have just taken delivery of our second CCD for the échelle. The quantum efficiency in the red is 75 per cent, a long way ahead of the approximately 2 or 3 per cent of hypersensitized Kodak plates of twenty years ago.

In February 1987 the famous supernova SN1987A became a naked-eye star in the Large Magellanic Cloud, and this became a regular spectroscopic target at Mt John for the next 15 months. The instrument used was the Florida spectrograph, for which the original five-year loan had been extended indefinitely (in fact it became Canterbury property in 1993). The supernova observations were the last major programme using solely photographic plates as the detector. MSc student Vincent McIntyre and technician-observer Alan Gilmore were the principal observers for this project, in which radial velocities of the ejecta were measured. It was an ideal research topic for a small telescope at the world's southernmost observatory, where we could observe the supernova throughout the year, even in the winter months when the Large Magellanic Cloud is low on the southern horizon.

The Florida spectrograph was orginally designed only for plates and even with image tubes it had a flexure problem. William Tobin did obtain some CCD spectra with it, but it was not suited to observations at all wavelengths. The most recent chapter in this story was the design and construction of Canterbury's own medium-resolution spectrograph in the early 1990s by Graeme Kershaw working with Peter Cottrell. This instrument, like the échelle, has Nankivell optics, and came into regular use in early 1995.

Stellar spectroscopy, in hindsight, has been a perfect type of research work for Mt John. Our telescopes are quite small, and our skies are often cloudy. But we have some excellent home-made but state-of-the-art instruments and detectors and a team of enthusiastic observers who have given New Zealand astronomy an excellent reputation for our work at Mt John.

Asteroids—and their New Zealand connections

Pam M. Kilmartin & Alan C. Gilmore

Alan and Pam are husband and wife and have been technician-observers at Mt John since the early 1980s. Besides participating in the observations of Christchurch-based astronomers, they conduct their own programme of positional astronomy.

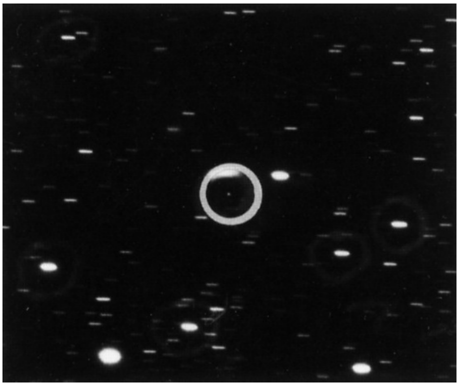
Between Mars and Jupiter there orbit thousands of tiny worlds called asteroids or minor planets. The objects in this belt are the leftovers of the rocky and metallic stuff that formed the inner planets—Mercury, Venus, Earth and Mars. All asteroids are small—the biggest is 1000 km across—and appear starlike in a telescope. The only way to recognize an asteroid is to know its position in the sky. This requires an accurate knowledge of its orbit. The orbits of asteroids are strongly affected by Jupiter's gravitational pull, and are continually changing.

A few asteroids cross the orbits of the inner planets. They are called Near-Earth Asteroids or NEAs. They are of great interest not least because sooner or later they may hit a planet, perhaps Earth. When an NEA comes close to Earth it can be studied by radar. Many are also possible targets for spacecraft.

Meteorites come from the asteroid belt. Linking the different orbits of meteorites to those of asteroids could tell us which meteorites were chipped from which asteroids. That would add more information about the early solar system.

All these studies first require that the asteroid orbits are accurately known. Over the past twenty years, fourteen of them at Mt John, we have photographed asteroids to measure their positions in the sky. From these measures the orbit calculation is refined. We give particular attention to NEAs and other asteroids in peculiar orbits. Several NEAs have been studied by radar following Mt John observations. Our measures were also particularly helpful for aiming the cameras of the Galileo spacecraft when it passed the asteroid Gaspra. In 1994 we tracked the NEA Geographos for the Clementine spacecraft flyby. Sadly the spacecraft's computer broke down and it was unable to reach Geographos.

Occasionally a 'new' or undiscovered asteroid will by chance appear on our photographs. If there is time and clear weather, we then try to track it so that its orbit can be roughly calculated. If the asteroid has not been tracked in previous years then it will count as our discovery. Once its orbit is accurately known—and that usually requires several years of follow-up



The Amor asteroid 1982 DV photographed on 20 March 1982 using the 20-cm f/4.5 Cook astrograph at Mt John. During the half-hour exposure the telescope tracked the asteroid, which consequently appears as a dot (circled). The motion of the asteroid against the background of stars smears the star images into trails 1.5 minutes of arc long.

observations—the Minor Planet Center in Cambridge, Massachussetts, assigns it a permanent number. Then the discoverers can suggest a name for it. The name, along with an explanatory citation, has to be approved by an international committee.

So far we have named eight of our discoveries. All honour New Zealand astronomers or places. The following are brief notes about each one:

(2434) BATESON is named after Frank M. Bateson who has directed the Variable Star Section of the Royal Astronomical Society of New Zealand for more than 60 years. Dr Bateson led the site survey that decided Mt John was the best place to put an observatory.

(3081) BEATRICE TINSLEY. Professor Tinsley was a world authority on the chemical evolution of galaxies. She was a graduate of Canterbury University and became a Professor at Yale University. Sadly, she died at the early age of 41.

(3142) JONES. Albert F. Jones of Nelson is internationally-renowned for his visual observations of variable stars and comets. He discovered comet 1946 VI and was an independent discoverer of Supernova 1987A in the Large Magellanic Cloud.

(3305) CEADAMS. Charles Edward Adams (1870-1945) was New Zealand Government Astronomer and Seismologist 1912-36. He began the transmission of radio time signals in New Zealand, and was internationally known for innovations in astronomical calculations and instrumentation. (There was already an asteroid 'Adams'.)

(3400) AOTEAROA. This was the first asteroid to be discovered from New Zealand, though not the first to be named. 'Aotearoa' is usually taken to be the Māori name for New Zealand although originally it referred only to the North Island.

(3521) COMRIE. Leslie John Comrie (1893-1950) was a New Zealander famous for his work in computational science and an authority on the production of mathematical tables. He was among the first to apply commercial office calculators to scientific computing.

(3563) CANTERBURY. Named for the province, and for Canterbury University of which Mt John University Observatory is a field station.

(3810) AORAKI. Aoraki, or Aorangi in northern dialects, is the Māori name for Mount Cook. The name is also given to the region in which Mt John lies, east of the mountain.

Several other New Zealanders have asteroids named after them, but not from discoveries by us. In order of permanent number they are:

(2064) THOMSEN. Named in memory of Ivan Leslie Thomsen (1910-1969), director of the Carter Observatory, Wellington 1945-69. Following this he was briefly Astronomer-in-Charge at Mt John University Observatory. Our comet and asteroid astrometry began at the Carter Observatory using the 16-inch (41-cm) telescope obtained by him. (2064) was rediscovered by us in 1977.

(2537) GILMORE. The Directors of the Minor Planet Center named this one after us by way of thanks for our comet and asteroid tracking. At the time it was one of the few such observing programmes in the southern hemisphere.

(3130) HILLARY. Named in honour of Sir Edmund Hillary by Antonin Mrkos, a Czechoslovak astronomer who worked with Hillary in Antarctica during the International Geophysical Year 1957-58.

(3907) KILMARTIN. The Director of the Minor Planet Center named this for Pam in recognition of her work in the identification, measurement and computation of comet and asteroid positions.

(5097) AXFORD. Named in honour of William Ian Axford by discoverer Edward Bowell. Dr Axford, who was knighted in the 1996 New Year's Honours List, is a Canterbury graduate and one of New Zealand's most distinguished scientists. He is world-renowned for his contributions to magnetospheric, heliospheric, cometary and cosmic-ray physics and interstellar gas dynamics. He has also provided strong leadership in promoting spacecraft missions, including the highly successful Giotto mission to Comet Halley in 1986.

It had long been thought that Asteroid (1249) RUTHERFORDIA was named after Ernest, Lord Rutherford of Nelson, the 1908 Nobel Prize winner whose portrait features on the $100 banknote. Quite recently it has been found that the discoverer, Karl Reinmuth, named it after the city of Rutherford in New York State. The asteroid was discovered and named in the 1930s, before the formal citation procedure was established.

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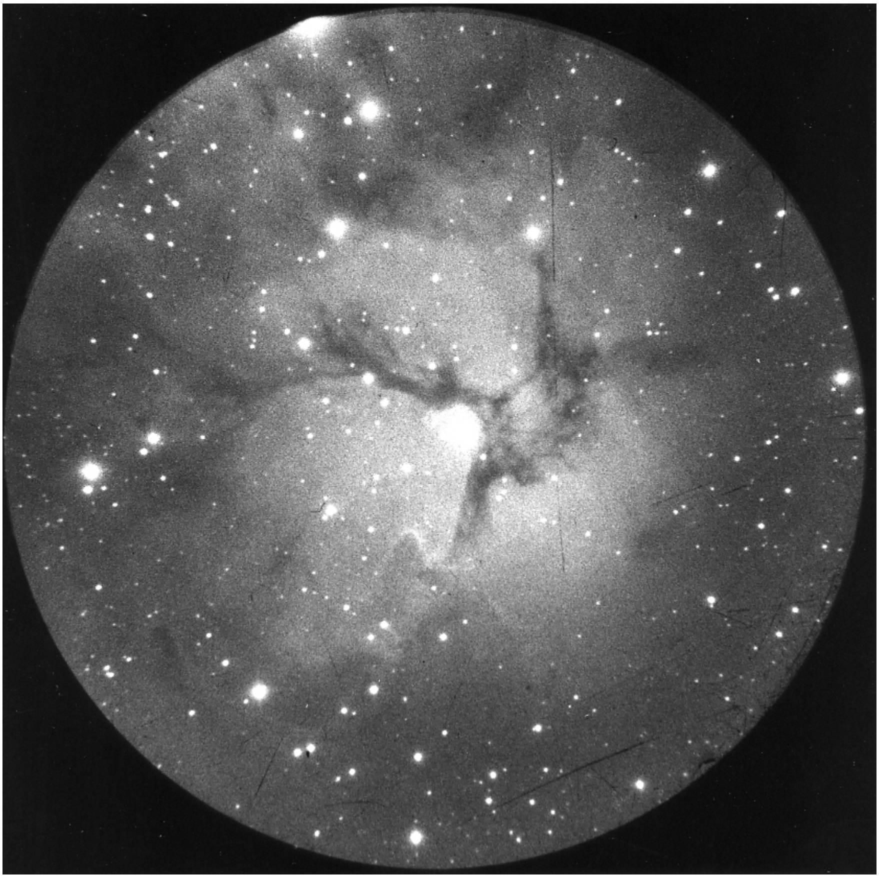


The glowing gas and obscuring dust lanes of the Triffid Nebula are recorded in this Mt John image-tube photograph from 1976.

Twenty-five years—last seen going that-a-way…

Mike Clark

Mike began work at the Observatory in 1971 and was its Resident Superintendent from 1980 until early 1996. Here he reminisces—and lets some cats out of the bag.

A quarter of a century ago I went to a magic place with a breathtaking landscape. The contract was for one year.

At that time the area was quite remote and exhibited a warm and friendly atmosphere that has somehow drifted away as Tekapo village has developed into a place of week-end baches and lunch stops on the route to Queenstown. Likewise, the Observatory has undergone a process of advancement and progress in pursuit of changing trends and requirements. A constant comparison with other, much larger institutions often fails to recognize that a PhD structure based on astronomical observations only delivers results every three years or so, and makes for a relative trickle of publications; and then to a very select audience.

My early years at Mt John were almost totally concerned with operating a photographic sky patrol, into which I poured my heart and soul for those who wanted the data. It was not unusual to miss out on sleep for one day, and sometimes two. This could lead to strong physiological effects like headaches, dizziness etc. The desire to squeeze as many plates as possible out of the conditions was very strong and became something of a manic goal.

After a few years, one patrol was replaced by another. The cycle started again! By this time, however, global warming effects were perhaps starting to make themselves apparent in the form of clouds. This made observing a bit of an uphill struggle compared to earlier times.

Life at the Observatory is dominated firstly by the weather, secondly by the continuing introduction of new equipment and the associated observing programmes, and thirdly by the characters that come and go. The latter have laid down a history ranging from the hilarious to the infuriating.

One amusing event (for everyone else) was an early character's attempt to glean some orbital information from a satellite. The plan was to photograph the satellite and to add some fiducial timing marks to the resulting trail using a clock-driven solenoid to physically 'shake' the camera. The radio link to the time signals was lost, and in desperation manual synchronization was resorted to by using a hammer on the camera! This seemed OK, but unfortunately the blows were applied to what would have been along the trail instead of across it! I say 'would have been' because there was a date error due to the confusion between Universal and Local Time. The poor guy was wrought. However, he moved on to surpass that by processing the backing paper instead of the film! But who would have guessed that he had in fact put the film (thinking it was the paper!) into a dark box and so saved the day—until the stars showed his elongations along the wrong axis. A very nice chap though—and he survived.

A person, still active in astronomy, once was in a hurry to dry a hard-earned photographic plate in order to return to Christchurch. He propped the processed plate up in the sun to dry, but on his return he found the emulsion had all slithered to the bottom! Eta Carinae should never look like that.

There was also a guy who had a propensity to drive off the road. A visit to a swamp; another time an exciting trip through a farm fence with a student; a total whiteout once. He left for Christchurch early one morning when a bright idea about clean windscreens struck him. So into the washer bottle went some photographic water softener. Halfway down the mountain road – give the screen a squirt – bam! Instant frozen window, no vision, straight into a ditch stranded on the universal and gearbox. It could have been much worse.

I haven't escaped the fun mill. Bought another car – put it into gear – jacked up car front – car takes off heading for lake: first experience of front wheel drive! Stories like this abound, but they need to await a much later date to re-surface.

Whilst the once-daily ties to met. reports and seismograph operations have long gone, the sheep, rabbits (between 3-yearly poisonings) and the extraordinarily violent weather remain. Intruder level has greatly decreased since the public walkway and stock fence were installed.

Undoubtedly the greatest single influence on Mt John operations has been the acquisition of the One-Metre Telescope. Because of its large aperture, almost all development emphasis has been focused on this instrument and hence it attracts nearly all observational projects. It is by far the most used telescope at the Observatory. Efforts to upkeep and maintain this telescope within a full-use regime have been largely successful to date. It remains to be seen if this can be kept up in the future.

As the hair greys, memories return of nights on the telescope; and I listen to this year's skylarks unseen high above. The frustration level creeps ever lower with today's trivialities, and the reasons for life seem to shift their ground as you realize that there is not as much in front of you as has already passed. One can only hope that one's contribution is appreciated.

Despite all the difficulties, Mt John has been a wonderful and unusual opportunity in my life. At times it has seemed like the boundaries of life itself.

The McLellan One-metre Telescope—an overview

John Hearnshaw

The impetus for the McLellan project and subsequent guidance was provided by John. He tells how it all came about.

Mt John University Observatory was founded in 1965. In 1970 and 1975 two 60-cm aperture reflecting telescopes had been installed there, both of American manufacture. The idea of building a larger telescope for Mt John germinated in the late 1970s; one of the smaller reflectors had not been working well, and the remedy entailed a complete rebuild of the mounting and drive system, which was undertaken in the Physics Department workshops between 1977 and 1979 by Graeme Kershaw and Morrie Poulton.

It was this work on the Optical Craftsmen telescope that gave us the confidence to think of bigger things, a telescope in the 1.0 to 1.5 metre range, so that we could compete more effectively in international astronomical research. At that time I had introduced stellar spectroscopy to Mt John, both using a spectrograph belonging to the University of Florida and also the échelle spectrograph, which we had built in the 1970s. Spectroscopy was ideal for our climate, but was wasteful of photons, and to be done well on all but the brightest stars, a larger telescope was essential.

A meeting in my office with Graeme Kershaw and Garry Nankivell (the latter then at DSIR's Physics and Engineering Lab) in 1978 laid the groundwork for the One-metre Telescope project. We quickly concluded we had the expertise for the job, and estimated that the cost of telescope, building and dome would be NZ$ 150 000 (1978 dollars). That was the sort of back-of-an-envelope guess that made us think it was a feasible sum to raise and enabled the project to be launched. At the same time, we sought quotations for 1-m class telescopes from several commercial manufacturers, including Grubb Parsons, Zeiss and Boller & Chivens. These quotes were generally in the range of $750 000 to $2 million for the telescope alone, and seemed to be well outside our likely budget. We decided that a 1-m telescope was the largest we could reasonably build ourselves, mainly because of the physical constraints in our workshop, including the available ceiling height and the lack of an overhead hoist.

In the event, by 1981, our figure for the do-it-yourself instrument was revised to $200 000 (1981 dollars) for the telescope and a commercially available dome, reducing slightly to $180 000 if we could make the dome ourselves. The building was removed from the costing at this stage.

The McLellan Telescope during trial assembly in the Machines Laboratory of the Department of Electrical & Electronic Engineering. Pictured extreme left is Morrie Poulton. Graeme Kershaw is at extreme right.

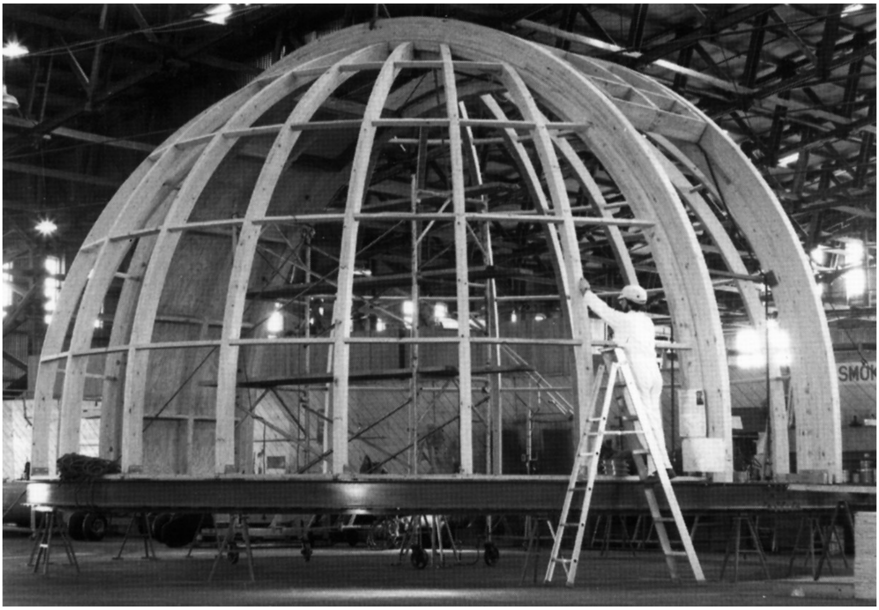
These figures were entirely for materials and components, and in the event proved to be reasonably accurate. In those days salaries and overheads were not part of the accounting exercise.

Prof. McLellan (Head of the Department of Physics) negotiated with Mike Collins at DSIR for the secondment of Garry Nankivell to Canterbury for six months, for his work on the primary mirror. In this way the project in effect became a joint University-DSIR one. Norman Rumsey, also from DSIR's Physics and Engineering Lab, undertook all the optical design work. Funding was seeded by a small initial grant from the University in 1979, and together with the launch of the appeal that same year with Frank Bateson as secretary, we officially were able to commence the project when Garry Nankivell arrived in Christchurch in May 1981.

The optics were made from Schott zero-expansion Zerodur ceramic and the mirror grinding and polishing machine was loaned without charge from the Fund for Astrophysical Research, an organization set up by Dr Theodore Dunham, Jnr in the United States, which had an interest in promoting southern-hemisphere astronomy. The machine had originally come from St Andrews in Scotland before being used by the Fund for a telescope in Tasmania; it was shipped to Christchurch from Melbourne. The cost of the primary mirror blank was DM 40 550.

The design of the One-metre Telescope was fairly conservative in most respects; we opted for a conventional single-pier asymmetric equatorial mounting. There would be two cassegrain foci at f/8 and f/13.5. The most unorthodox aspect was Norman Rumsey's advocacy of the Dall-Kirkham optical system, with its ellipsoidal primary and spherical secondary. He argued that this system was very much easier to fabricate than the more-usual Ritchey-Chrétien one, and he was able to design field-correcting lenses for the f/8 configuration that gave good images over a 1.7-degree field. Axial images were likely to be even better in quality than those from a Ritchey-Chrétien design. I accepted these arguments, and the result is that we have the largest wide-field Dall-Kirkham telescope in the world (the 1.5-m coudé auxiliary feed telescope at La Silla in Chile is larger, but is only used for axial images).

Some other aspects of the telescope do however merit comment for their unusual design. The encoders built by Ross Ritchie are an ingenious mix of absolute and differential encoders; for example, in declination the absolute encoders are read from the wheel every degree, but the differential encoding from the worm will record fractions of a degree to a 10 arc second resolution. For the primary mirror support, two bicycle tyres partially filled with mercury provided the radial flotation support system, while at the secondary mirror Graeme Kershaw devised a successful swivelling top end that allowed a quick change from f/8 to f/13.5 configurations. For a while we looked closely at the spherical oil pressure bearing used by Zeiss for their 1.2-m telescopes. We even approached Zeiss for permission to copy this design, which turned out not to be patented. In the end we chose the more conventional route with roller bearings, which as it happened were donated free to the project by SKF New Zealand Ltd. The mechanical design was entirely by Graeme Kershaw and the electronics by Ross Ritchie in the Physics Department.



The skeleton of the dome takes shape in a hangar at the RAFNZ base at Wigram.

Mechanical construction of the whole telescope took nearly five years in our workshops. Most parts were fabricated in house. The gears however were purchased from the Philadelphia Gear Corporation, after obtaining advice from colleagues at Kitt Peak Observatory in Arizona. The 480-tooth, 48-inch right ascension wheel was from nickel-bronze and was driven through a stainless steel worm. The pair cost US$ 8550. For the declination drive a slightly smaller wheel (360 teeth, 36-inch diameter) cost US$ 7475. These were relatively major items acquired from overseas. Once again our drive system was conventional. Some of the larger sections of the telescope's polar and declination axles were fabricated by Hamilton Engineering in Christchurch.

The 8-m hemispherical dome was an integral part of the project. Graeme Kershaw and Ross Ritchie had inspected a wooden dome on the 40-inch telescope at Siding Spring, and we decided to copy many aspects of this. Bruce Bradshaw was in charge of dome design and construction. One immediate problem was to find a floor area of sufficient size and with a high enough ceiling for the dome construction to proceed. In the event we were able to negotiate the use of half an aircraft hangar at Wigram Air Force Base for some six months or more. The dome was constructed from curved laminated wooden ribs and marine grade plywood, covered with an aluminium skin. It sat on a circular steel joist. Our dome budget was $50 000 and the work took Bruce Bradshaw and Wayne Smith about 8 months in 1983-84.

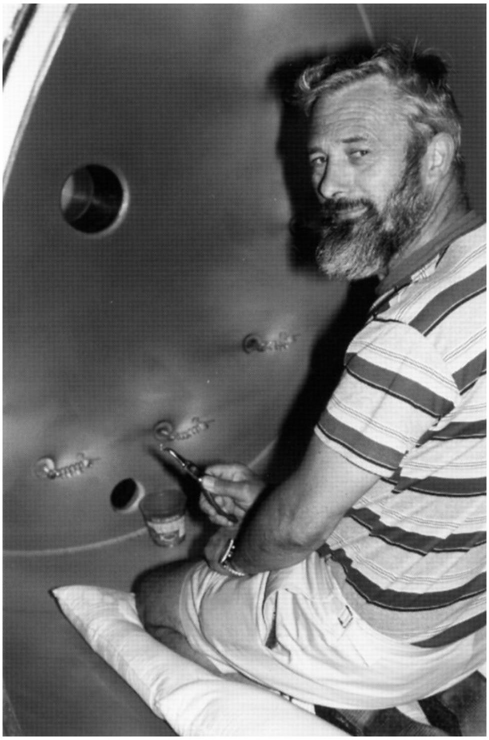
Another part of the project was an aluminizing plant to be installed at Mt John large enough to take the 1-m primary mirror. Bruce Bradshaw designed and built this, using a large cylindrical vacuum tank that had been lying disused in the Department for some years, originally being the outer shell of an infrared spectrometer. Large diffusion and mechanical backing pumps were purchased to convert the old spectrometer into the aluminizing chamber. The mirrors are realuminized annually.

The telescope was finally nearing completion in 1985. Our problem then was to find an assembly area on campus where the whole structure could be erected and the drive and control systems tested. The Physics Department had no suitable area with an overhead crane, but we were able to negotiate with Prof. John Bargh at Electrical and Electronic Engineering for the use of their Machines Laboratory for the summer of 1985-86. This area had the height required and an overhead crane, and was an ideal solution.

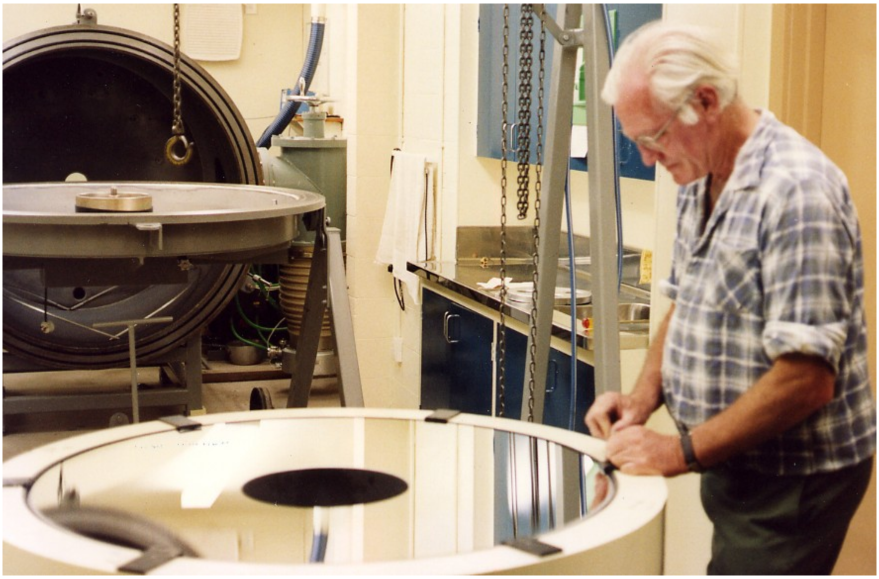
The building for the One-metre Telescope at Mt John is another story. It was our original intention to build a separate building for the telescope at the Observatory, but in 1983 the American satellite-tracking station, the Observatory's neighbour on Mt John, closed. Ownership of the tracking station building reverted to the government, and the University at once negotiated for a lease on this building to house the telescope. The tracking-station building required substantial modification for this purpose, especially for the observing area. This whole process, and that of designing and installing the moving observing floor, were taken out of the hands of the Department and were managed by the Buildings Section of the University Registry together with design input from the Ministry of Works, using a grant for this purpose from the University Grants Committee. We had substantial input into the layout of the new part of the building and the operational requirements of the floor, but not with the construction side. Rumour has it that the building cost substantially more than the telescope!

The telescope was essentially complete but not installed on site in December 1985, when the Department was host for a symposium of the International Astronomical Union on Instrumentation and Research Programmes for Small Telescopes. The symposium attracted 133 participants from many countries. It was an ideal way to launch the new instrument. Installation at Mt John followed in February 1986 and first light was in March of that year. My first observation was a spectrum of Halley's comet with the Florida spectrograph. The official opening was on 11 July 1986

Right: Mike Clark, who was the Observatory's Resident Superintendent until recently, hangs loops of aluminium wire on the heating coils of the vacuum aluminization chamber at Mt John.



Below: Observatory technician John Baker examines the freshly-aluminized primary mirror of the McLellan Telescope. The mirror is realuminized annually in order to maintain high reflectivity.



at the Observatory, following a lunch at the Alpine Inn in Tekapo village. Two bus loads of invited guests attended, and there were speeches by Prof. Wybourne (Head of the Physics Department), by Mr Caldwell (the University's Chancellor) and Prof. D. Hall (Chairman of the University Grants Committee). The opening day was attended by a heavy snowstorm, and it was touch-and-go whether the buses would be able to reach the top of Mt John. Thanks to the snow-ploughing of Mike Clark, they made the ascent successfully. The telescope was named the McLellan telescope in honour of Prof. Alister McLellan, under whose departmental headship the project had commenced.

It is interesting to speculate on the circumstances that allowed us to build the telescope in the way we did. First, the project was only possible because of a dedicated and experienced team of about eight technical staff within the Department, plus the services of Norman Rumsey and Garry Nankivell from DSIR. Secondly, it was possible because the 1980s were still the days when full-cost accounting was not being practised in New Zealand universities, and therefore a large do-it-yourself project appeared to be very much cheaper than buying commercially and off-the-shelf. What is more, we were able to come to gentlemen's agreements with DSIR, with the NZ Air Force, with the Fund for Astrophysical Research, with the Ministry of Works, with the Department of Electrical and Electronic Engineering and with Dr Frank Bateson for their services to be donated or supplied to the project. In addition both the Lottery Board and the University Grants Committee agreed to fund the project over several years rather than in one lump sum; this was not their customary practice, but from our point of view was an ideal solution.

It is also interesting to note that the telescope design might well have been quite different had we started the project a few years later. We did not go the route of a fast, thin-mirror telescope, nor did we adopt the popular alt-azimuth mounting seen in many recent instruments, which could in turn have resulted in a smaller dome and a cheaper building. We might well have had a friction drive instead of the expensive worm and wheel gears. All these design features could have created quite a different telescope. Nevertheless, the McLellan One-metre Telescope has been an outstanding success story. Perhaps the message is that a fairly conservative but superbly engineered design together with hand-crafted construction leads to a reliable end-product. The last decade of astronomy at Mt John has seen unprecedented growth and success, a testimony to the skills of the technical staff who built the McLellan reflector.

Funding the One-metre Telescope

The One-metre Telescope was funded over a number of years from grants and donations from the University Grants Committee, the Lottery Scientific Research Distribution Committee, the University of Canterbury, the Department of Physics at the University and from a public telescope appeal.

The aim was to raise $ 200 000 (1981 NZ dollars) from all these sources over about 4 years. The appeal was launched in mid-1979, with Dr Frank Bateson, the former Astronomer-in-Charge at Mt John, as the appeal secretary, while the late Sir Val Skellerup, then Chairman of Directors of Skellerup Industries, was the chairman of the appeal committee. Frank Bateson sent out many hundreds of letters for the appeal, mainly to prominent local and national business firms, to notable New Zealanders, and especially to former University of Canterbury graduates. The letterhead featured the University crest and a stylized telescope under the Southern Cross.

Although the appeal raised a relatively modest sum in comparison to the other sources, it was nevertheless influential in persuading the UGC and Lottery that the fund-raising effort was serious, and it gave the whole project some welcome publicity. A broad cross-section of individuals, organizations and companies made donations to the appeal.

The following is a break down of how the telescope was funded:

	$
Golden Kiwi Lottery: seven grants 1980-84	92 500
University Grants Committee: five grants 1980-84	70 000
University of Canterbury: four grants 1979-84	27 000
Physics Dept., University of Canterbury: three grants 1981-84	11 700
Telescope appeal: Ninety-five donors	22 212
Total funding:	223 412

The funds raised covered the cost of the telescope construction (excluding all labour costs and overheads) and the dome. The building and rising floor were funded from separate grants from the UGC directly to the University.

List of donors

$ 1000 or more

Bank of New Zealand, Ilam Branch, Christchurch
Fund for Astrophysical Research, New Hampshire, USA
Prof. L.S. Hearnshaw, West Kirby, UK
Kingdon-Tomlinson Bequest, Wellington
J.R. McKenzie Trust, Wellington
N.J. Rumsey, Lower Hutt
Skellerup Industries Ltd, Christchurch

$ 500-$ 999

Bank of New South Wales (Westpac), Wellington
Prof. R.H.T. Bates, Christchurch
C.S. Barker, Wellington
The Sargood Bequest, Dunedin
South Canterbury Savings Bank, Timaru

$ 100-$ 499

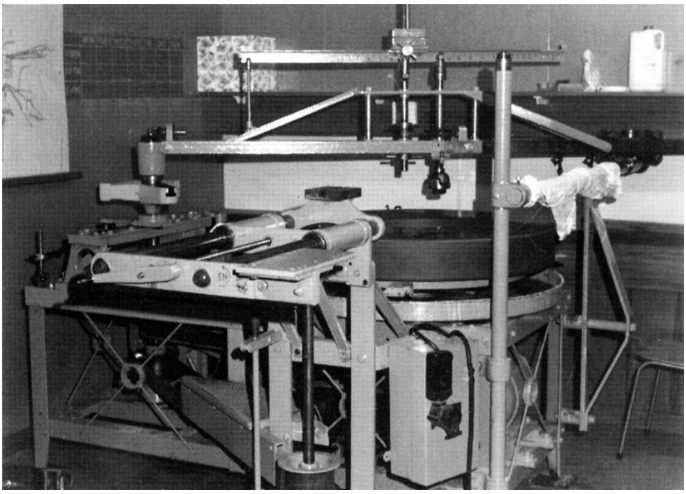
The Canterbury Farmers Cooperative, Timaru
R.J. ('Bob') Charles, Christchurch
Sir Charles Fleming, Wellington
Charles Alexander Fleming Trust, Wellington
A.C. Gilmore, Wellington
Miss R. Holden, Opotiki
Mrs M.F. Mackenzie, Christchurch
N.T. Munford, Palmerston North
N.Z. Cement Holdings Ltd, Christchurch
N.Z. Solenoid Co., Christchurch
Sir Walter and Lady Norwood, Wellington
Dr W. Orchiston, Clayton, Australia
J.H. Polson, Christchurch
L.W.P. Reeves, Christchurch
Miss J.B. Ross, Sumner
J.V. & S.I. Salisbury, Kaiteriteri
M. Schroder, Hamilton
R.G. Simmers, Wellington
W.A. Sutton, Christchurch
Tekapo Ski Field, Lake Tekapo
Whakatane Astronomical Society
Sir Frederick White, Canberra, Australia
Prof. F.B. Wood, Gainesville, Florida, USA

Less than $ 100

H. Abraham, Canberra, Australia
Sir Robert Aitken, Birmingham, UK
W.H. Allen, Dunedin
F.P. Andrews, Wellington
G.K. Armstrong, Queenstown
Dr H.H. Atkinson, Swindon, UK
Auckland Astronomical Society
Auckland Observatory
Aulsebrooks Ltd, Otahuhu
L.C.L. Averill, Christchurch
Prof. R.M. Barrer, Chislehurst, UK
J.M. Bishop, Timaru
C.A. Blazey, Wellington
G.L. Blow, Wellington
Dr D.T. Brash, Auckland
Prof. J. Broomfield, Canberra, Australia
Brown Bros. Ltd, Christchurch

Less than $ 100 (cont.)

Canterbury Motors Ltd, Christchurch
Christchurch Guild of Weavers and Spinners
Dr G. Cochrane, Auckland
A.B. & D.F. Cook, Christchurch
N.E. Dalmer, Levin
Prof. W. Davidson, Dunedin
J.R. Dawson, Christchurch
Lord Elworthy, Timaru
M.G. England, Pukerua Bay
Prof. H.E. Field, Christchurch
Fraemohs Industries Ltd, Christchurch
H.A. Fullerton, Wellington
D.R. Goodman, Wellington
Dr G. Hall-Jones, Invercargill
J.O.F. Hamilton, Christchurch
G.C.D. Herdman, Auckland
E.A. Lee, Christchurch
Dr H.B. Low, Lower Hutt
R.D. Lumsden, Wellington
Mace Engineering Ltd, Christchurch
J.H. Macky, Taupo
P.B. Maling, Christchurch
Dame Ngaio Marsh, Christchurch
J.F. McCahon, Parnassus
Sir Terence & Lady McCombs, Christchurch
N.C. McLeod, Wellington
J.M. Mitchell, Waikanae
Prof. A.D. Monro, Paremata
E.J. Neilson, Christchurch
Sir Alfred North, Auckland
N.F. Roberts, Christchurch
Standard Optical Co. of Australasia Ltd, Christchurch
Star Wood Products, Timaru
L.F. Story, Christchurch
Bishop P. Sutter, Nelson
Tait Electronics, Christchurch
E.B.E. Taylor, Christchurch
Dr M. Thomas, Dunedin
Timaru Herald Co. Ltd, Timaru
Mrs R. Tyson, Auckland
Bishop A.K. Warren, Christchurch
Dr R.A. Wooding, Linden
Wrightson NMA, Christchurch



The one-metre mirror blank in place on the machine lent by the Fund for Astrophysical Research on which it was figured.

The optical system

Norman Rumsey

Norman designed the optics for the McLellan Telescope. He tells of the various considerations involved.

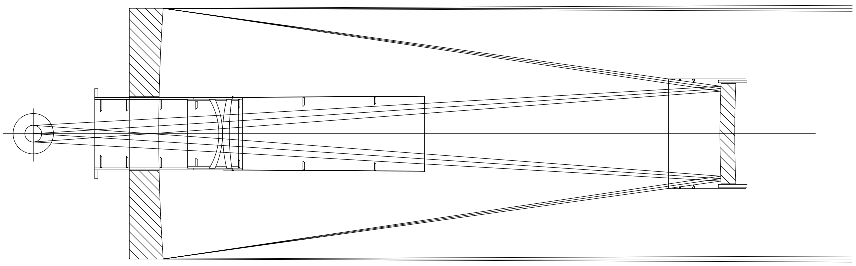
Image-forming optical systems such as photographic objectives and small telescopes are almost always made from arrangements of lens elements with spherical surfaces. The surfaces must be curved to produce images (though occasional flat surfaces may also be included). Of all possible curved surfaces only spherical surfaces can be produced at all easily with the incredible perfection of shape and smoothness required in optical systems. However, lens systems are not good at treating different colours all in the same way. Astronomers are interested not only in light of all the diffferent colours of the visible spectrum, but also in the invisible shorter-wavelength ultraviolet and longer-wavelength infrared. Further, high quality optical glass becomes extremely expensive for lens elements of more than a few centimetres diameter. Therefore large astronomical telescopes have in the past been built using mirrors only. Now many telescopes are built using a combination of mirrors and lenses. In this case the lenses are either very thin compared with their diameters, or small in diameter compared with the largest mirror in the system.

It is possible to build a telescope that uses just one concave mirror to form the image of an area of sky. However, if the mirror is spherical the image is not sharply defined. The profile of the reflecting surface has to be a parabola, not a circle, in this case. Such a mirror is much more difficult to make well than one with a spherical surface; but astronomers are willing to pay for the more expensive paraboloid mirror because they need the best image sharpness that is possible. Even with this extra trouble they get sharp images of only a small area of sky. Away from the middle of the field of view, star images become enlarged and pear-shaped. Thus we see that the images formed by optical systems can suffer from defects known as *aberrations.* The symmetrical blurring that arises when the mirror is a sphere instead of a paraboloid is known as *spherical aberration.* The pear-shaped blurring that can arise for images away from the middle of the field of view is known as *coma.* There are an infinite number of different aberrations that can affect images, so it is not easy to achieve near-perfect images over a wide field of view. The most practical way of maintaining good definition over extended fields in astronomical telescopes is to use mirrors to do most of the work of redirecting light rays so that images are formed, and to include lens elements also that deviate light rays relatively little but nevertheless control aberrations.

When the McLellan telescope was being designed, it was intended that it should be used primarily for photoelectric photometry and spectroscopy of stars one at a time; while a lower priority was photography of extended areas of sky to determine accurate positions of comets and asteroids. For the primary applications it was desirable at that time for the telescope to have a long focal length. A convenient way of achieving this is to start with a concave 'primary' mirror with an aperture as large as one wishes the telescope to have (in this case, one metre) but with a shorter focal length than desired. Before the collected light reaches the focus of the primary mirror a convex 'secondary' mirror intercepts the light and reflects it through a central hole in the primary mirror to a final focus beyond it. Use of a convex secondary mirror in this way results in the equivalent focal length of the combination of mirrors being some multiple of the focal length of the primary mirror that depends on the geometry of the system. In this case the focal length of the primary mirror is 3.5 metres, and the equivalent focal length of the combination is 13.5 metres. The distance from the secondary mirror to the final focus is about 3.17 metres, so the system is very compact compared with its equivalent focal length.

Such an arrangement of mirrors was first suggested by a Frenchman named Cassegrain in about 1672. For nearly two-and-a-half centuries everyone assumed that the two mirrors must be given profiles that correct the spherical aberration of each mirror separately. This meant that the profile of the concave primary mirror had to be a parabola (as mentioned above) and that of the convex secondary mirror had to be an hyperbola. Indeed, this makes sense if the primary mirror is sometimes to be used by itself. However, a convex hyperboloid surface is even more difficult to make well than a concave paraboloid. If the primary and secondary mirrors are always to be used together it is possible to correct the spherical aberration of the combination without making each mirror well-corrected separately. Thus one can insist that the convex secondary mirror shall be spherical for ease of manufacture (and also easier alignment in the telescope). Then the primary mirror must be an ellipsoid that lies about three-quarters of the way from a sphere to a paraboloid. This possibility was realized independently by Dall in England and Kirkham in the United States during the 1930s. The coma of the system is worse than that of the classical Cassegrain; but this does not matter in our case since the coma is zero in the middle of the field and only one star at a time is to be studied. The McLellan Telescope uses Dall-Kirkham optics, and is the second-largest optical telescope in the world of this type.

The secondary application of the telescope, requiring photography of

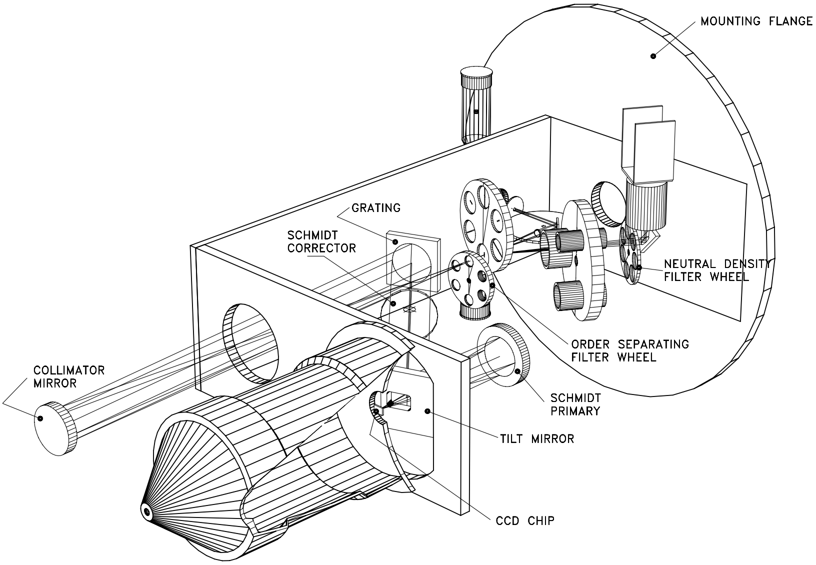


Schematic drawing of the f/8 optics of the McLellan One-metre Telescope.

extended areas of sky, calls for a shorter focal length than was appropriate for the primary applications, so that a larger angular field on the sky can be recorded on a photographic negative of given size. Further, the image sharpness should ideally be uniformly good over the whole area of the extended image. The shorter focal length is achieved by replacing the original secondary mirror by another which is also convex and spherical, but is larger in diameter, a little closer to the primary mirror and less strongly curved than the original secondary. The new equivalent focal length is a little less than 8 metres. A close approach to uniformly good definition over the image is achieved by the use of two lens elements in the optical path just before the light reaches the hole in the primary mirror.

It is interesting that technical developments since the telescope was built have made the shorter-focal-length system more popular than was originally expected. Photoelectric photometry used to be done with a photomultiplier. This is effectvely a detector of light with just one large pixel. Now a CCD is commonly used. This is a solid-state, multi-pixel detector with very small pixels which are better matched to the star images produced by the shorter focal length system. Also the smaller image scale of this system increases the chance that the images of other stars of interest will fall within the detecting area of the CCD and can be photometered at the same time. Another development is the use of an optical fibre to convey light from a star image in the focal plane of the telescope to a spectrograph. This can now be housed in a temperature-controlled enclosure in a fixed position instead of being attached directly to the end of the telescope and moving around with it. The larger apex angle of the cone of light converging to a star image produced by the shorter-focal-length system better suits the characteristics of optical fibres.

Mt John University Observatory looking north. The One-metre Telescope building and dome are in the foreground.



A cut-away drawing of the recently-completed Medium-Resolution Spectrograph *which will be used for spectroscopic monitoring of fainter stars, though with less spectral detail. The optics were designed and built by Garry Nankivell. The mechanical work was by Graeme Kershaw and the electronics by Geoff Graham.*

Fabrication of the optics

Garry Nankivell

Figuring the primary mirror took only 5 months, as Garry explains.

On 22 November 1980, a decision was taken to proceed with the making of a one-metre aperture cassegrain-type telescope using an f/3.5 primary mirror with a secondary mirror to produce an f/13.5 focus. The initial brief called for the provision of a fully corrected axial image for stellar spectroscopy using the existing cassegrain échelle spectrograph that had been made at an earlier date. A joint project was set up between the Physics Department of the University and the Physics and Engineering Laboratory ('PEL') of the former DSIR. The responsibility of the optical design and fabrication was assigned to the Optics Section of PEL.

The one-metre diameter primary mirror blank arrived in Christchurch from Germany on 18 May 1981, followed the next day by the secondary mirror blank. Both blanks were made from Schott Zerodur, a glass ceramic with a near zero temperature expansion coefficient. A ground-floor laboratory was converted into a temporary optical shop, where the Fund for Astrophysical Research's grinding and polishing machine had been set up at the north end. A testing path was also set up adjacent to the machine, where the 250-kg primary mirror could be moved using an overhead gantry and be set up for testing. The plano back of the mirror was resurfaced to remove diamond tooling marks and wider edge bevels were generated on both faces. June 26 saw the start of surfacing on the concave face. This had previously been diamond milled to curve by Schott, to avoid the lengthy task of curve grinding. At this stage the central 285-mm diameter core was trepanned from the mirror using a large radial drill, prior to fine surfacing and polishing. The grinding tiles were removed from the large cast aluminium optical tool and replaced with an annular layout of 75-mm square pads of polishing pitch. The mirror was brought to a complete spherical polish over a five-day period and the centre then deepened with a smaller tapered-facet polishing lap. This took another three days of hard polishing simply to remove the small amount of glass that made the difference between a spherical and ellipsoidal profile.

Initial testing used the well known Foucault zonal test simply to measure the extent of aspherising. Final testing made use of an all-reflecting Offner compensator which used two opposing concave spherical mirrors, made from Zerodur, to pre-aberrate the test wavefront which in turn would be balanced by the desired profile on the primary mirror. This technique

Graeme Kershaw cuts the central hole in the McLellan primary mirror.

of null testing certainly makes for easier interpretation of the mirror profile and allows the optical engineer to arrive at the desired shape with greater certainty. The use of Zerodur allowed a much greater number of figuring runs to be undertaken each day. Because Zerodur has a near-zero thermal expansion coefficient, the mirror could be tested immediately without needing to wait for the heat generated by the polishing to dissipate. The mirror was declared complete on Labour Day, 26 October 1981, after three tedious days of alternating survey and fine retouching. The assistance of David Buckley on those final days is gratefully acknowledged.

The spherical convex secondary was made back in Lower Hutt at the Physics and Engineering Laboratory. Also made at a slightly later date were the two 285-mm diameter lenses made of BK7 glass for a zero-power field corrector, along with the 400-mm diameter convex secondary. This allows the telescope to be converted to an f/7.7 wide field system, in response to those users requiring a wider field for astrometric or CCD observations.

The mechanical design of the McLellan One-metre Telescope

Graeme Kershaw

Graeme first started work with the Department of Physics thirty years ago when the University was situated in the Arts Centre in Christchurch. He has been closely involved with the Mt John University Observatory and the Astronomy group since 1970.

Mt John University Observatory purchased its first medium-size telescope in 1970 and its second in 1975. Both of these 61-cm telescopes became the back-bone of astronomical research in New Zealand.

By 1978 it was becoming clear that a larger telescope was going to be necessary if serious research was to continue at Mt John. Ideas were floated and a preliminary study was conducted into procuring or building a 90-cm telescope. Initial estimates of the cost of buying an instrument were in the order of NZ$ 750 000, and although some ideas were discussed for the local construction of such a telescope, nothing more was done until 1980. In that year more serious consideration was given to: a possible price ceiling, type of telescope, type of mounting, method of construction and building design.

It was clear that about one third of the purchase price of a factory-built telescope was all that would be available for this project. It was, therefore, necessary to come up with a design which could be constructed in our modest workshops. If all drawing and construction work was done by our own staff, it was felt that a one-metre aperture telescope was a realistic undertaking.

On that basis the rest of the design parameters fell into place. The optics were to be built by Gary Nankivell of the Physics and Engineering Laboratory of DSIR in Wellington. The mechanical and electronics design and construction was to be undertaken by the Physics Department at the University of Canterbury. Any components that were too large to be constructed in the Physics Department would be built by C.W.F. Hamilton Engineering.

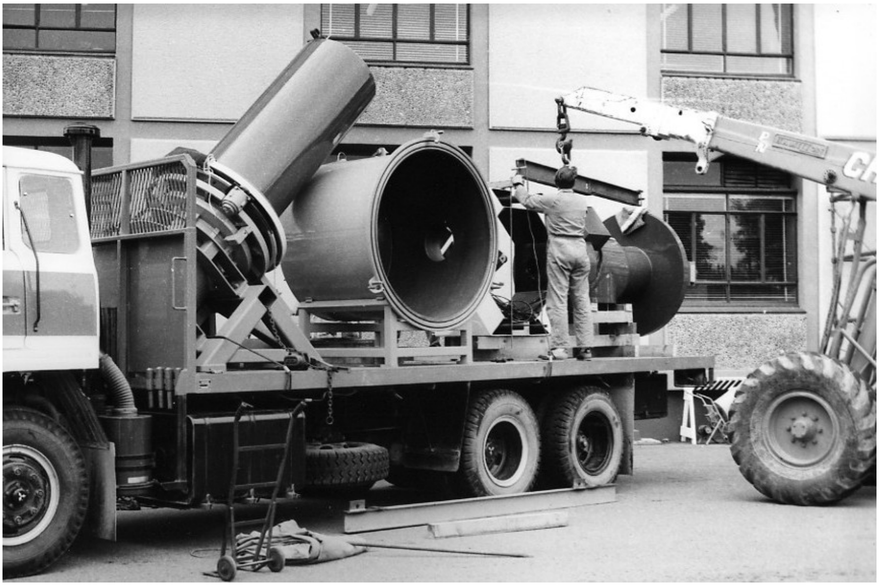
The telescope was to be a one-metre cassegrain reflector figured as a Dall-Kirkham. This would greatly simplify the construction of the optical components and reduce the time needed to figure the optical surfaces. Provision was also made for an extra secondary mirror and corrector lenses, to allow the telescope to be used at a smaller focal ratio with a wider field of view.

An equatorial, torque-tube type mounting was chosen i.e. a large-diameter axle with the telescope on one side and a counterweight on the other. This provided the best possible space for any instruments to be attached to the back end of the telescope. The Observatory had, or had planned, several instruments including high- and medium-resolution spectrographs, photoelectric photometers and CCD cameras. The mounting must not restrict the positioning of the telescope with any of the above instruments in place.

The building to house the telescope was also designed at this stage but no firm proposal was decided upon. The cost of such a building was an unknown factor as was the final location on the mountain top. These questions and others were resolved when the Baker-Nunn satellite-tracking station, already situated on a prime spot on Mt John, was vacated in mid 1983. This facility was modified and a new dome built ready for the completed telescope in 1985.

Other details of the design were finalized in late 1980. It was decided to use conventional worm and wheel drives for both axes of the telescope, each driven with a special 5-phase stepper motor. These stepper motors have a very large dynamic range and are able to run from fast slewing speed down to the slowest guide speed without the use of extra gearboxes.

Morrie Poulton machines the cell for the primary mirror in the Physics Department workshops in Christchurch.



The disassembled McLellan Telescope is loaded onto a lorry outside the Physics Department in Christchurch ready for the 250 km journey to Mt John.

Both right ascension and declination axes use a combination of absolute and incremental encoders. These were readily built in house, thus saving many thousands of dollars on buying commercial units. The stepper motors and encoders would enable the telescope to be pointed to 10 arc seconds in declination and 1 second of time in right ascension, with slewing and setting speeds in the range 2 arc seconds/second to 2 degrees/second.

It was decided to include a rising floor in the final design of the observatory. This would provide a safe and stable platform for the observers as well as an invaluable tool for telescope maintenance. The rising floor would also simplify the removal of the primary mirror for the annual routine of realuminizing the mirror.

Design and construction of the telescope began in May 1981 and continued until August 1985. All sections of the telescope and its mounting were designed to be as small as possible to keep construction and handling difficulties to a minimum. Despite this, three major sections (the polar axis column, the torque tube, and the declination axis assembly) had to be constructed under outside contract. Where possible, each sub-assembly was tested to make sure it performed to expectation. By September 1985 the painting and testing was complete and the whole telescope was ready for a trial assembly in the Machines Laboratory of the Electrical & Electronic Engineering Department.

With the whole telescope assembled it was then possible to evaluate the entire system. The performance of the drives, encoders, mirror support and electronic controllers was constantly tested until December 1985. Any weaknesses found were rectified and retested before we were satisfied. Some problems were experienced with the lack of stiffness in the RA drive but it was impossible to quantify the problem without directly viewing the stars. It was decided to deal with this and any other minor difficulties during commissioning. At this point the whole telescope was dismantled and packed ready for transport to Mt John at the begining of February 1986.

Installation and assembly in the dome was done with the aid of a large crane and a very skilful driver. Each large piece was lowered in turn through the slot in the dome and bolted in place. The whole process took three days but at the end of that time the telescope worked to expectation. The final finishing touches to the electronics racks and covers for the more delicate components of the telescope were complete by May 1986.

Commissioning and testing of the complete instrument went on until a few days before the opening ceremony on 11 July 1986. The most important task was to aluminize the primary mirror for the first time, which in itself was an exacting, painstaking, but rewarding task. Those who witnessed the fresh aluminium coating for the first time will never forget its splendour and purity.

Since the official opening, the telescope, now called the McLellan One-metre Telescope, underwent further improvment with the installation of the alternative f/7.7 optical system, light baffles and the tidying up of a few annoying problems such as drive resonances and unwanted flexure. The rest of the building was developed at the same time, providing excellent data and control-room facilities along with the adjacent aluminizing plant.

In the following ten years the McLellan Telescope has proven to be reliable and effective. It has undergone several changes to keep up with the increasing demands made by the technology of modern astronomy and now stands as the major instrument for astronomy in New Zealand.

The people and the money

Speakers at the inauguration of the McLellan Telescope praised the individuals involved in the project. The University of Canterbury Chronicle *reported.*

NEW TELESCOPE OPENED

New Zealand's biggest telescope, now piercing deep into the southern sky from the Mount John University Observatory at Tekapo, has been named the McLellan One-metre Telescope in honour of Professor A.G. McLellan, the former Head of the Physics Department, during whose term the observatory was established and the building of the telescope begun.

At a ceremony held in the building housing the One-Metre Telescope on 11 July 1986, a crowd of seventy who braved snow and bitter cold heard the University's Chancellor (Mr Charles Caldwell) say that if there was one person who could be described as the 'father' of the new instrument, it was Alister McLellan, Head of the Physics Department for 28 years, during which time the idea of the Mount John University Observatory was born. The idea became a reality almost precisely 21 years ago and with the new instrument the Observatory might well be described as having reached maturity. All of those exciting developments were backed solidly by Prof. McLellan, who saw astronomy as an exciting and important field for the Physics Department. Mr Caldwell said 'It would have been pleasant had the telescope been completed to mark his retirement two years ago, but the Department had an even better idea. To mark Prof. McLellan's outstanding contribution to the successful completion of this project, the new instrument will be officially named the *McLellan One-metre Telescope.*'

The chairman of the University Grants Committee (Prof. David Hall) unveiled the plaques, one recording the official naming of the telescope and the other giving the names of the University and DSIR technicians who contributed to the construction of the instrument between May 1981 and February 1986.

The Chancellor described the construction of the One-metre Telescope as a splendid exercise in scientific co-operation, and an exercise in public support. The University was grateful on all counts and he expressed that gratitude to the many whose expertise, courage, co-operation, donations and sheer hard work brought the project to a successful conclusion.

There was warm applause as the Chancellor complimented Graeme Kershaw, of the Physics Department, who, he said 'has worked, lived, eaten and slept One-metre Telescope for the last five years. After renovating one of the existing telescopes at the Observatory, he reckoned he could build a complete instrument, and today's ceremony is a triumphant

Prof. Alister McLellan at the inauguration of his eponymous telescope.

vindication of that quiet confidence in his own ability. He designed the instrument and oversaw its construction. Perhaps he will now agree that the sleepless nights, the long hours, the frustrations and the annoyances were worth it…'

'Much of the construction of the instrument was undertaken by Maurice Poulton, also a technician in the Department. It was exacting, skilled work and the result speaks for itself. The dome was designed by another Physics technician, Bruce Bradshaw, who won an award for the design and S.B. Hemmingsen and W.G. Smith assisted in the construction. The sophisticated electronic controls were designed by technicians Ross Ritchie and Ray Borrell.'

'Keeping a fatherly eye on all this activity was the Department's senior technical officer, Bob Tyree, who successfully dovetailed a series of complex operations to ensure a smooth conclusion to the project.'

'Clearly there is a wealth of technical talent in the Physics Department,' Mr Caldwell said. 'There is also wisdom. The technical staff were aware of their limitations and they knew their talents did not extend to the design of the optical system nor to the figuring, grinding and polishing of the primary mirror. For that key rôle we have to thank the Department of Scientific and Industrial Research for their willing collaboration. The DSIR's Assistant Director-General, Michael Collins, is with us today and I trust the message he will take back with him is that despite the tighter application of the 'user pays' policy, scientific collaboration still has many virtues. The University is convinced of that.'

'Mr Norman Rumsey, of the DSIR's Physics and Engineering Laboratory, at Gracefield, designed the optical system and the laboratory also released New Zealand's top optical craftsman, Garry Nankivell, for six months to come to Ilam and grind the mirror, using equipment lent by the Fund for Astrophysical Research, a private American foundation. Mr Nankivell has enhanced his high reputation with his craftsmanship on this occasion. The one-metre mirror, 135 mm thick and weighing a quarter of a tonne, was a thing of beauty when ground and polished,' the Chancellor said.

'A number of companies assisted with the casting of parts, the RNZAF station, Wigram, found space in a hangar for the construction of the dome and it has been erected in buildings which formerly housed a United States Air Force satellite tracking camera,' he added. About 100 trusts, companies and individuals contributed to a public appeal organized by Frank Bateson, who carried out the site surveys which established Mt John as the premier site for the Observatory prior to its official opening in 1965.

The Head of the Physics Department (Prof. Brian Wybourne) said the new instrument...could perhaps be described as a device for supporting the 100 micrograms of aluminium used for silvering the primary mirror, but in fact it was a product of advanced technology and the skills of many different people...

Prof. Wybourne expressed the University's thanks to the people of Tekapo, the County Council and the Army base for their assistance and co-operation with the Observatory and its staff, an example being the efforts made to limit light pollution from the village. He also paid a tribute to the observatory staff, led by the Resident Supervisor, Mike Clark, who worked in conditions which few people would tolerate.

'The Physics Department is proud of this venture and will now produce scientific results,' Professor Wybourne said.

UGC FUNDS FOR MT JOHN

An exception to an otherwise inflexible rule enabled the construction of the new telescope to proceed, the Chairman of the University Grants Committee (Prof. David Hall) revealed at the opening ceremony at Mt John.

Prof. Hall said the Observatory had a fine reputation based on its smaller telescopes. In 1978 a proposal emerged for a major step forward, a one-metre aperture telescope, and it was clear the financial implications could be great.

'In 1978 the cost of such an instrument from a normal commercial manufacturer would have been about $ 800 000,' he said. 'We swallowed hard. That figure is best put into perspective by telling you that the total UGC Research Fund, the fund from which all major equipment in all disciplines in all seven universities is to be supported, stood in 1978 at $ 750 000.'

An ambitious project was devised for building the telescope. It was a joint project between the Physics Department of the University of Canterbury and the Physics and Engineering Laboratory of DSIR. They would design and construct the telescope themselves, and they would seek to purchase only those components which they could not fabricate on their own.

'On this basis, and with healthy neglect of such considerations as salaries for the many, many hours that would be required, the budget was reduced to $ 114 000, or $ 200 000 with the cost of the building included,' Professor Hall said.

'If those figures do not bear too much relation to the reality as we now know it (the building alone cost considerably more than that), we should reflect that a healthy optimism is the first prerequisite of any major research project, and this one was no exception. . . '

'Those responsible sought continued financial support through the period of construction and were looking for this from the University, from the Golden Kiwi Lottery Board, and from the UGC Research Fund. Most of you will know that the Research Fund was at that time under the control of three very wise and respected men, the late Sir Arthur Nevill, Frank Askin, and Prof. Hugh Parton. These three were accustomed to administer a fund which is woefully inadequate to meet the demands upon it, and at the same time retaining the confidence and respect of the university community.'

'This they managed by adhering to one golden rule: that grants were finite and applicable in the year in question only, and never ever would they accept a continuing commitment against funds for future years. That was a good administrative principle, but to my knowledge they only once allowed an exception. So impressed were they with the telescope proposal, and the contribution in effort that the proposers were themselves making, that they did accept that they would continue support over the necessary years for this one.'

'The record shows that grants were made. . . to a total of about $ 90 000, and we had no illusions that we had not necessarily heard the last. Having aided and abetted the construction of the telescope, the UGC was scarcely in a position to decline to house it, and was very pleased to provide the grant for this handsome building.'

'At times an enterprise such as this must take the appearance of a tug-of-war between the proposers and the granting agencies. At the end of the road however there is the accomplishment, the reality of this splendid research facility. Those who have been responsible for it may now and most justifiably be very, very proud; those of us who have been in the position to give some assistance here or there are more conscious of the privilege that that was,' Prof. Hall said.

A night in the observing chair

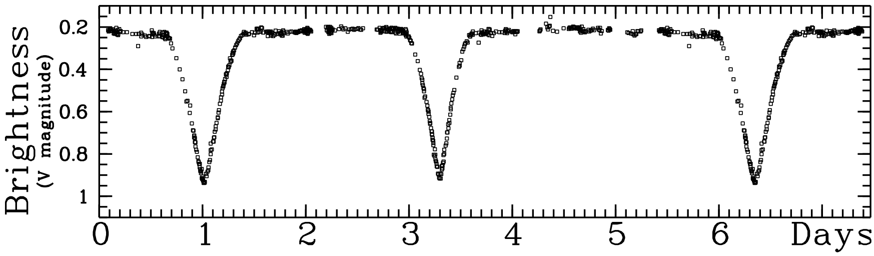
John Pritchard

John is nearing completion of his doctorate in astronomy. He tells what it's like observing.

On clear nights at Mount John, the work of the astronomers usually begins several hours before sunset. Today's modern equipment requires extensive preparation and this work can often be done before it gets dark, thereby saving every precious minute of darkness for actually observing stars.

These pre-dusk preparations are usually relatively straightforward, but time consuming. For the Charge-Coupled Device (or CCD) camera you first have to fill the holding container with liquid nitrogen, a cooling fluid which will keep the chip at $-110\,^{\circ}$C all night. Then you must fire up the computer, check the clocks, and make a few trial exposures to ensure that the camera is operating correctly and will produce the best possible pictures. Finally, you open the dome and take off the mirror covers so that the telescope can cool to the air temperature, putting an end to view-disturbing plumes of rising hot air. These things done, it's time to observe stars, but for this of course it must be dark. While you wait, there is perhaps time to snatch a few moments to watch the Sun sink slowly behind the Southern Alps to the west. It's an enchanting view, but the first stars to appear before your eyes quickly remind you there is a telescope waiting, and what's more, it can show you far more than you could ever hope to see with your bare eyes.

So into the dome where the telescope awaits. Push a few buttons and the motors begin to hum telling you the telescope is ready to be aimed and that it will then faithfully follow whichever star you point it at, all night if need be, as the star traces its arc across the sky from east to west. You check your lists and your charts, and decide on your first star for the night, a brilliant blue supergiant, 300 times the size of our Sun, or perhaps a faint white dwarf as massive as the Sun but only the size of the Earth. Pushing some more buttons brings the telescope to life. It sweeps its gaze across the vault of the sky, until finally this one special star, amongst the billions in our Galaxy, is the centre of view. Now you unleash all the power of modern technology that is at your finger tips, probing the secrets of this star. In a matter of seconds if the star is quite bright, or perhaps twenty minutes later if the star is rather faint, the camera will have finished acquiring its picture and you will be able to see it almost immediately on the computer monitor.



A high-quality light curve that John has observed for his doctoral thesis using the McLellan Telescope. The star is HV 982, an eclisping binary in the Large Magellanic Cloud. Like HV 2274 (see page 40), it shows an eccentric orbit and apsidal motion.

Later analysis with advanced computers will be needed to glean every last grain of information from the image. In the meantime it's time to observe another star, or perhaps the same one again, depending on your current project.

When dawn finally comes, it's time to turn off the telescope motors, cover the mirrors, close the observatory up, and climb into the welcoming comfort of bed to sleep away the day in preparation for the next night.

In the middle of winter the nights are long. The Sun sets at about 5 pm and does not return until perhaps 7:30 am, and of course, on top of a mountain in the middle of the South Island of New Zealand, it's bitterly cold and you must constantly be wary that at almost any moment it could start snowing. Snow is pretty, but not so good for telescopes! But these long, cold nights have their advantages. Many hours of darkness allow many observations to be made, so it is possible to plough through an observing programme rapidly. And the coldness means the nights are often very still and therefore ideal for observing.

In the summer on the other hand, there are only perhaps six hours of darkness, but it's warm enough all night for shorts and tee-shirts! On these nights, unless one is observing just one or two stars all night, it is a constant race from one star to another, trying desperately to observe as many stars as possible before the Sun returns to hide them in its immense brilliance.

In some ways it is unfortunate that technology is now so advanced, because it means that most of the work of astronomy is reduced to controlling the computers. But each new star requires a final check using your own eyes, just to be certain the computer really has done what you wanted. These are perhaps the best times, when you gaze out upon the heavens in all their splendour and perhaps imagine yourself reaching out to touch the sparkling gems, or perhaps ponder what eyes might be looking straight back at you from worlds so far from our own.

The Townsend Telescope— a century of university stargazing

William Tobin

In 1891 James Townsend, an early settler then in his seventies, donated a prized possession to Canterbury College. The gift, as a report in *The Canterbury Times* for 19 February 1891 glowingly put it, was 'a splendidly constructed equatorial telescope, with all the many and costly optical and mechanical fittings connected therewith.' The telescope had a respectable, six-inch diameter lens and had been crafted in 1864 by the famous English telescope-making firm of Thomas Cooke & Sons of York and London. Townsend had used the telescope for many years from his home at the north-east corner of Park Terrace and Salisbury Street, though it is unclear precisely when he acquired it.

The telescope was certainly on Park Terrace in 1882 when Townsend had lent it to the British expedition that was visiting New Zealand to observe one of the rare transits of Venus across the face of the Sun, from which, via parallax, it had been hoped to determine an accurate value of the solar distance. Since the polar axis of an equatorial telescope must be built for the latitude at which it will be used, it seems probable that the telescope was built for a client in Canterbury. The Cooke company archives record an order on 26 August 1863 for a 6-inch equatorial from Hamilton

From The Canterbury Times, *17 November 1894:*

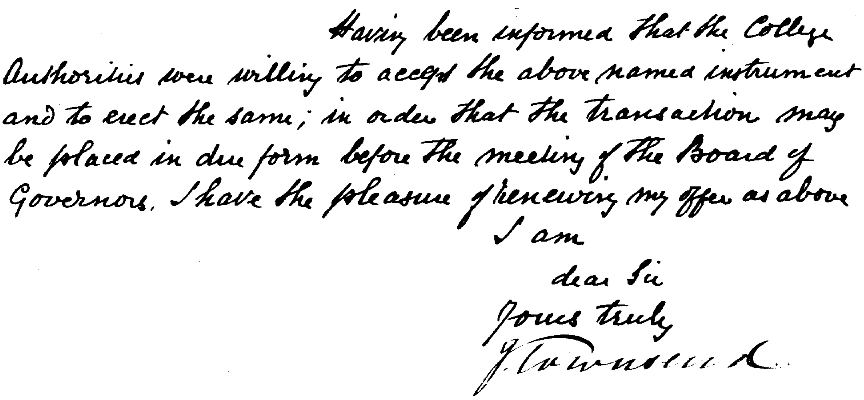
OBITUARY. Mr James Townsend, an old Canterbury colonist, died yesterday at the age of 79. The deceased gentleman arrived in the ship Cressy with his relatives, and for some time lived at Ferrymead. He afterwards removed to Rangiora, and engaged in sheepfarming, but returned to Lyttelton and was for many years Clerk of the Magistrate's Court, and employed in the Customs Office there. Subsequently he came to Christchurch, and lived in a house which he had built on Park Terrace. He was unmarried and lived a retired life. He was a keen student of natural science, especially astronomy, and some time ago presented a large telescope to the Board of Governors of Canterbury College. He was also a man of musical tastes. Mr Townsend will be interred at Lyttelton…

The Townsend Telescope and its unusual dome with a 180° slit. Every year a senior astronomy student is appointed to run public viewing sessions. Pictured is Ashley Marles (BSc 1996) who was Townsend Observer in 1995. (Photo: D.C. Holmes)

Field, Esq., of Kearns, Major & Field, wharfingers of Upper Thames Street, Brixton, for which £150 were received the following February on account towards the (discounted) price of £300. The obvious inference is that Field was acting as agent for Townsend or some other purchaser in Canterbury.

The *Canterbury Times* report continued: 'Christchurch felt something of that wave of enthusiasm which bathed the world at the time of the Venus transit expeditions; and the enthusiasm hereabout showed itself in the collection of a modest sum by way of nucleus for an observatory. The silent work of interest has been going on since then, and the present value of the fund may possibly be as much as £400.' The money was offered to the College by the Astronomical Society of Christchurch on condition that an observatory be constructed.

The 1890s marked the depth of a long economic depression and College revenues were reduced. However a Supreme Court ruling allowed the College to use part of the Medical School Fund to build a biology laboratory. As part of this construction, a small tower was erected in which Townsend's telescope was installed in 1896. The cost of the tower and telescope installation was some £900. Sadly, Townsend had not lived to see his


Having been informed that the College Authorities were willing to accept the above named instrument and to erect the same; in order that the transaction may be placed in due form before the meeting of the Board of Governors, I have the pleasure of renewing my offer as above

I am

dear Sir

Yours truly

J. Townsend

James Townsend reiterates his offer in a letter to the College governors dated 11 June 1891. The handwriting appears to be that of a secretary.

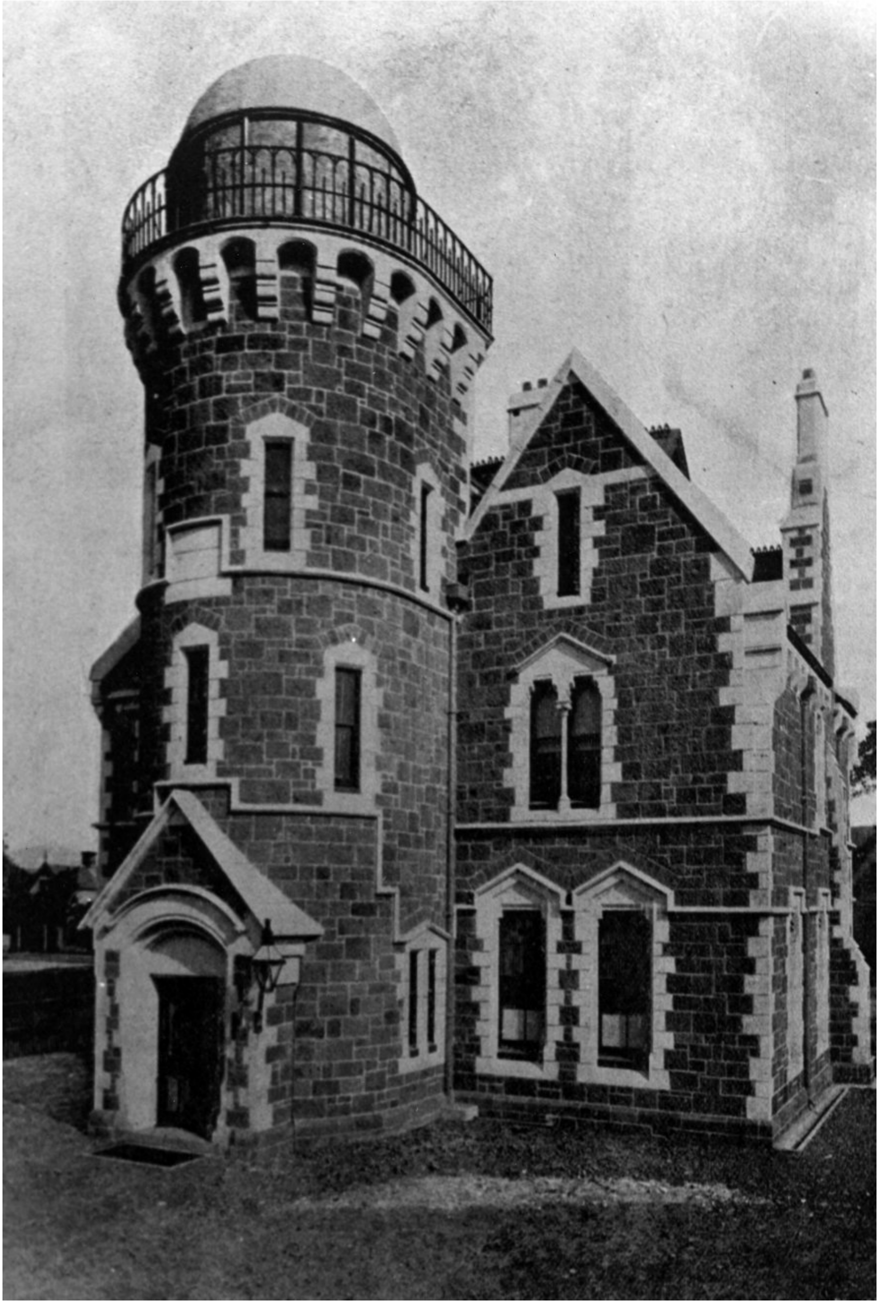
telescope in use again.

A Mr Walter Kitson of Sumner was appointed 'custodian' of the telescope at an annual honorarium of £50. Kitson was or had been with the Lands and Survey Office, and it was he who had used Townsend's telescope in 1882 for the transit of Venus observations. His new duties were: 'A. To keep the instrument in working order, clean, and in good adjustment; B. To be in attendance at the College four days or evenings in each month for the purpose of showing students or visitors what adjustments in the instrument are necessary; how they are performed; how an observation is made and the general use of the instrument.' Kitson reported that 'I find

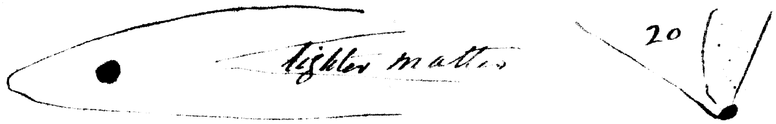
From The Press, *9 September 1893:*

SEARCH LIGHTS

WHERE *is that telescope?* Some years ago Mr Townsend presented to the Canterbury College an equatorial telescope of great value. He attached to his gift the condition that the instrument should be put to use. For years he had used it himself, and recorded a series of interesting astronomical observations. But, in a broad and liberal spirit, he did not wish to restrict its usefulness to himself and his own circle of personal friends. He cast about for a means of making it more widely available, and at the same time advancing the cause of education and science. So he presented it to the Board of Governors as to a body that might fairly be assumed to have that cause at heart. *Where is that telescope?*



*The newly-completed observatory tower (*The Weekly Press*, 19 March 1896).*



Observations of the comet of May 1901 by Walter Kitson. When first seen on April 28, the comet was 'not unlike an egg with the yolk representing the nucleus about 2 or 3 times its diameter distant from the edge of the surrounding envelope' (left sketch); a fortnight later Kitson 'estimated the length of the comet at 10 degrees… the comet was attended by an illuminated shadow at an angle of about 20° or 30° radiating from the Sun' (right sketch).

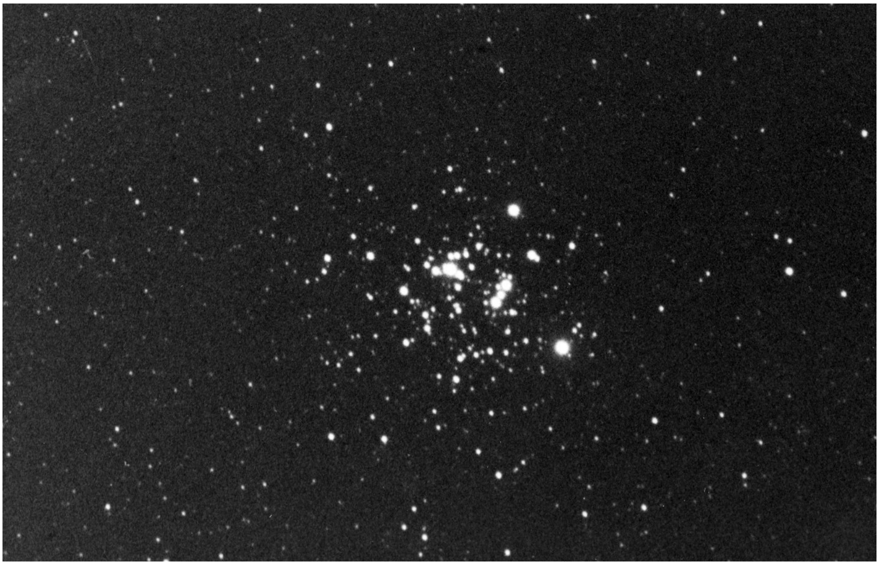
it almost impossible to work the telescope entirely alone and am obliged to employ my son to help, shifting shutters &c. In term time, I have no doubt, I shall be able to secure the help of some student. It would be as well that some stated time should be fixed for my attendance, say between the hours of 7 and 10.30 p.m. on every Friday night.' (These are almost the hours at which the Townsend Telescope still opens for public viewing!)

The original dome was made of wood and canvas and by 1914 had rotted. It was replaced with another of the the same materials which in due course suffered the same fate. In 1950 a solid steel dome was installed, designed by Bernie Withers of the Department of Electrical Engineering. It has the unusual feature of a slit reaching the full 180° from horizon to opposite horizon.

Kitson lamented that the setting circles were 'much worn,' though 'as a telescope for observing phenomena it is as good as the day it left the maker.' The Townsend Telescope remains in near-unmodified condition, bristling with brass fittings and wooden-handled controls. (Its glittering appearance is is due to refurbishment twenty years ago by Wayne Smith and Graeme Kershaw of the Physics Department.) To track the stars the telescope is driven by a clockwork motor and aerodynamic regulator. The telescope's original appearance, however, is a sign that it has hardly been used for scientific research, in which case it would inevitably have been modified and modernized.

But scientific research is not the only reason for maintaining a telescope. The night sky is a mighty and awe-inspiring sight, made mightier with optical instruments. The Townsend Telescope is the only part of the old University site still in University ownership and is maintained by the Department of Physics & Astronomy for public viewing.

In the early 17th century Galileo was amazed and astonished when he turned his new-made telescope on the sky and discovered mountains



The Jewel Box cluster (κ Crucis) photographed with the Townsend Telescope (compare with the digital image on page 28).

on the Moon, the moons of Jupiter, the phases of Venus and the 'handles' (rings) of Saturn. For one hundred years Cantabrians have been enjoying these and other sights through the Townsend Telescope. The revolution in human understanding that resulted from Galileo's observations has long been assimilated, but the modern man or woman is no less amazed than Galileo when looking up a telescope for the first time.

SOURCES

Cooke company records, University of York, UK.
Correspondence and press-cutting archives, University of Canterbury Registry.
J. Hight, *A short history of the Canterbury College,* Whitcombe & Tombs, Christchurch, 1927.
G.R. MacDonald, manuscript *Dictionary of Canterbury Biographies,* Canterbury Museum.
G. Strange, *The Arts Centre of Christchurch: then and now,* Clerestory Press, Christchurch, 1994.

The Townsend Telescope is open for public viewing from 8 pm on clear Friday nights during the period of New Zealand Standard Time. The sessions are run jointly by the Department of Physics & Astronomy and the Canterbury Astronomical Society. A recorded message is available on (03) 379-8751.

Mt John University Observatory Publications 1979–1995

This compilation updates an earlier compilation covering the period 1961–1979. It lists publications in astronomy:

(a) based on observations made at Mt John University Observatory, or

(b) written in the Department of Physics & Astronomy, or

(c) written about Mt John,

and is divided among the following categories :

In the listings, an asterisk (*) indicates a University of Canterbury staff member or student.

Research papers

Papers are listed alphabetically by year.

Hearnshaw, J.B.*
The Hα profile of the RS CVn binary HR 1099
Astronomical Journal, **83**, 1531-4 (1978)

Desikachary, K.* & McInally, C.J.*
Frequency Analysis of the early-type δ Scuti star HD 153747
Monthly Notices of the Royal Astronomical Society, **188**, 67-73 (1979)

Scarfe, C.
A progress report on NY Cephei
Journal of the Royal Astronomical Society of Canada, **73**, 258-62 (1979)

Desikachary, K.*
On some recent spectroscopic analyses of subdwarfs
Astrophysics Letters, **20**, 137-42 (1980)

England, M.N.*
A spectroscopic analysis of the Alpha Centauri system
Monthly Notices of the Royal Astronomical Society, **191,** 23-5 (1980)

Gilmore, G.F.*
Is PKS1921−29 a quasar with correlated radio and optical variations?
Nature, **287**, 612-3 (1980)

Gilmore, G.F.*
Optical monitoring of southern quasars II
Monthly Notices of the Royal Astronomical Society, **190**, 649-67 (1980)

Hearnshaw, J.B.*
Measuring stellar temperatures
I: *Southern Stars*, **28**, 109-17 (1980)
II: *Southern Stars*, **28**, 187-97 (1980)

Wood, F.B. & Austin, R.R.D.*
Two eclipses of AI Velorum
Monthly Notices of the Royal Astronomical Society, **193**, 867-74 (1980)

Collier, A.C.,* Hearnshaw, J.B.* & Austin, R.R.D.*
The southern RS CVn binary, HD 5303
Monthly Notices of the Royal Astronomical Society, **197**, 769-78 (1981)

Hearnshaw, J.B.*
Reduction techniques for échelle spectrograms
American Astronomical Society Photo-Bulletin, **26**, 9-13 (1981)

Trodahl, H.J., Sullivan, D.J. & Gibb, R.G.
Spectrophotometry of bright southern stars
Monthly Notices of the Royal Astronomical Society, **197**, 941-8 (1981)

Allen, W.H. & Edwards, P.J.
Some observations of the flare stars UU Ceti and Proxima Centauri
Southern Stars, **30**, 159-67 (1982)

Blow, G.L.
Photoelectric lunar occultations III. Some real results
Southern Stars, **29**, 160-68 (1982)

Collier, A.C.*
Discovery of two FK Comae stars in the southern hemisphere
Monthly Notices of the Royal Astronomical Society, **200**, 489-96 (1982)

Collier, A.C.*
A coordinated radio and Hα survey of southern RS CVn systems and related objects
Monthly Notices of the Royal Astronomical Society, **200**, 869-80 (1982)

Desikachary, K.* & Hearnshaw, J.B.*
The spectrum of Canopus II: analysis and composition
Monthly Notices of the Royal Astronomical Society, **201**, 707-21 (1982)

Hearnshaw, J.B.* & Desikachary, K.*
The spectrum of Canopus
Monthly Notices of the Royal Astronomical Society, **198**, 311-20 (1982)

Sullivan, D.J.
Fast photoelectric photometry
Southern Stars, **30**, 19-41 (1982)

Blow, G.L.
Lunar occultation
In *Solar System Photometry Handbook*, Genet, R.M. (Ed.) Ch. 9, Willmann-Bell (1983)

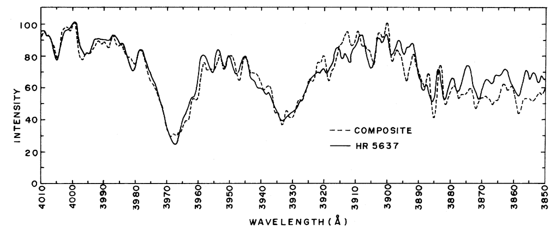
Bopp, B.W. & Hearnshaw, J.B.*
An Hα survey of southern hemisphere active chromosphere stars
Astrophysical Journal, **267**, 653-54 (1983)

McDonald, A.R.E. & Hearnshaw, J.B.*
The Wolf 630 moving group of stars
Monthly Notices of the Royal Astronomical Society, **204**, 841-52 (1983)

Tomkin, J., Sneden, C. & Cottrell, P.L.*
A search for duplicity in the weak G-band stars
Publications of the Astronomical Society of the Pacific, **96**, 609-12 (1984)

A'Hearn, M.F., Birch, P.V., Feldman, P.D. & Millis, R.L.
Comet Encke: gas production and light curve
Icarus, **64**, 1-10 (1985)

Noordanus, B.,* Cottrell, P.L.* & Ake, T.B.
HR5637: The unveiling of a binary
Monthly Notices of the Royal Astronomical Society, **212**, 931-38 (1985)



One approach to the analysis of stellar spectra is to build model stellar atmospheres which are compared with observations. Here observations and models are in good agreement. From: Noordanus, Cottrell & Ake (1985).

Bopp, B.W., Africano, J. & Quigley, R.
UBV photometry of ten southern hemisphere active chromosphere stars
Astronomical Journal, **92**, 1409-13 (1986)

Cottrell, P.L.* & Sneden, C.
A detailed kinematic and abundance analysis of old disk giants
Astronomy & Astrophysics, **161**, 314-26 (1986)

Lawson, W.A.* & Cottrell, P.L.*
The R Coronae Borealis star RY Sgr: shock wave phenomenon
Observatory, **106**, 169-70 (1986)

Begley, M.J.* & Cottrell, P.L.*
Evidence for departures from LTE in Na and Al in late-type giants
Monthly Notices of the Royal Astronomical Society, **224**, 633-40 (1987)

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The analysis of starlight: some comments on the development of astronomical spectroscopy 1815-1965
Vistas in Astronomy, **30**, 319-75 (1987)

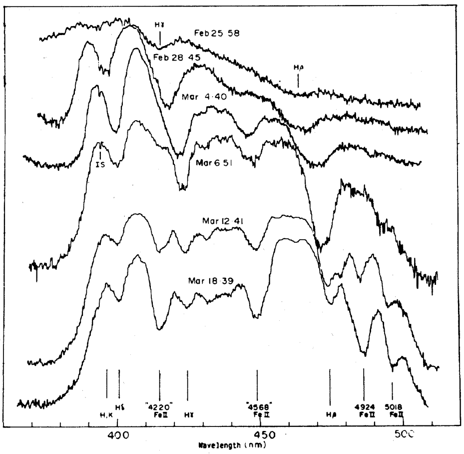
Leitherer, C., Forbes, D., Gilmore, A.C.,* Hearnshaw, J.B.,* Klare, G., Krautter, J., Mandel, H., Stahl, O., Strupat, W., Wolf, B., Zickgraf, F.-J. & Zirbel, E.
Photometry and spectroscopy of the O-type variable HD 167971
Astronomy & Astrophysics, **185**, 121-30 (1987)

Tobin, W.*
Foucault's invention of the silvered-glass reflecting telescope and the history of his 80-cm reflector at the Observatoire de Marseille
Vistas in Astronomy, **30**, 153-84 (1987)

Elgarøy, Ø., Jorås, P., Engvold, O., Jensen, E., Pettersen, B.R., Ayres, T.R., Ambruster, C., Linsky, J.L., Clark, M.,* Kunkel, W. & Marang, F.
Ultraviolet emission lines from the flare star AT Microscopii
Astronomy & Astrophysics, **193**, 211-21 (1988)

Hearnshaw, J.B.,* McIntyre, V.J.* & Gilmore, A.C.*
Spectroscopy of SN 1987a in the LMC
Journal of Astrophysics & Astronomy, **9**, 93-106 (1988)

Lawson, W.A.* & Cottrell, P.L.*
RY Sgr: pulsational period variations reinterpreted
Monthly Notices of the Royal Astronomical Society, **231**, 609-15 (1988)



The rapid variation in the spectrum of supernova 1987A in the thirty days following the explosion on 24 February 1987 is illustrated in these McLellan photographic spectra. From: Hearnshaw, McIntyre & Gilmore (1988).

Lawson, W.A.,* Cottrell, P.L.* & Bateson, F.M.
Observations of R Coronae Borealis (RCB) stars I: RY Sgr, Y Mus & U Aqr
Publications of the Variable Star Section Royal Astronomical Society of New Zealand, **14**, 2 (1988)

Reynolds, S.,* Hearnshaw, J.B.* & Cottrell, P.L.*
The spectrum of Canopus III: abundances of r- and s-process elements
Monthly Notices of the Royal Astronomical Society, **235**, 1423-38 (1988)

Ryder, S.D.*
A pre-discovery magnitude of Supernova 1987A
Southern Stars, **33**, 45-8 (1988)

Blow, G.L.
Reduction of photoelectric occultation data
In *The Photoelectric Photometry Handbook II,* Genet, D.R. (Ed.) Fairborn Press (1989)

Kershaw, G.M.* & Hearnshaw, J.B.*
High precision radial velocities using an optical fibre feed
Southern Stars, **33**, 89-97 (1989)

Kurtz, D.W., Matthews, J.M., Martinez, P., Seeman, J., Cropper, M., Clemens, J.C., Kreidel, T.J., Sterken, C., Schneider, H., Weiss, W.W., Kawaler, S.D., Kepler, S.O., van der Peet, A., Sullivan, D.J. & Wood, H.J.
The high-overtone p-mode spectrum of the rapidly oscillating Ap star HR 1217 (HD 24712)—results of a frequency analysis of 324 hr of multi-site photometric observations obtained during a 46-day time-span in 1986
Monthly Notices of the Royal Astronomical Society, **240**, 881-915 (1989)

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The R Coronae Borealis star NSV 6708
Monthly Notices of the Royal Astronomical Society, **240**, 689-700 (1989)

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Observations of R Coronae Borealis (RCB) stars II: 5 more RCBs
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The reclassification of the suspected R Coronae Borealis star SY Hyi as a semi-regular variable
Journal of Astrophysics & Astronomy, **10**, 151-5 (1989)

Pollard, K.R.,* Hearnshaw, J.B.,* Gilmore, A.C.* & Kilmartin, P.M.*
CF Octantis: an RS CVn-type variable with a prominent activity cycle
Journal of Astrophysics & Astronomy, **10**, 139-46 (1989)

Banks, T. & Budding, E.
Information Limit Optimisation Techniques applied to AB Doradus
Astrophysics & Space Science, **167**, 221-34 (1990)

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The dynamical mass of S Muscae
Astronomical Journal, **99**, 353-72 (1990)

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LB 1800: A bright eclipsing cataclysmic variable and a transient X-ray source
Astrophysical Journal, **355**, 617-26 (1990)

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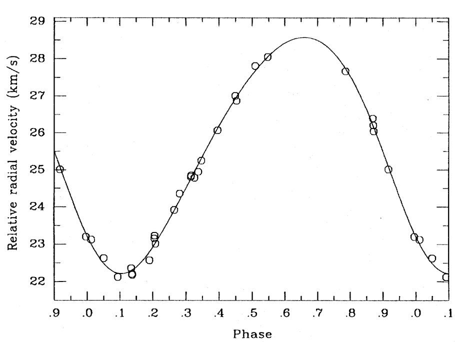

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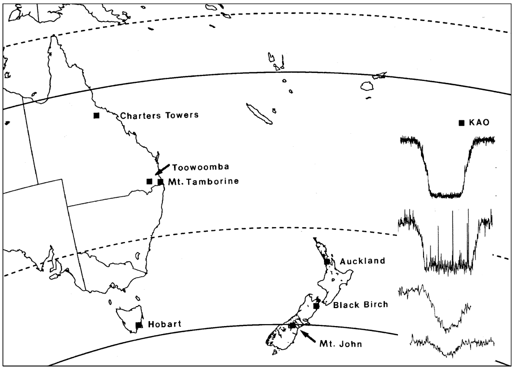
Pluto's radius and atmosphere: results from the entire 9 June 1988 occultation data set



Mt John was involved in the discovery of Pluto's atmosphere when Pluto passed in front of a distant star and occulted its light in 1988. The dashed lines show the predicted occultation track, but in fact the track fell further south (full lines), with Mt John at the edge. The gradual fading of the star's light at Mt John and Black Birch showed that Pluto's limb was not hard but softened by an atmosphere. The occultation was longer at Auckland, which was closer to the centre of the occultation track. NASA's Kuiper Airborne Observatory (KAO) observed the occultation from mid Pacific. The KAO recording is well defined because the aircraft was high above much of the distorting turbulence of the Earth's atmosphere. Adapted from: Millis et al., *(1993).*

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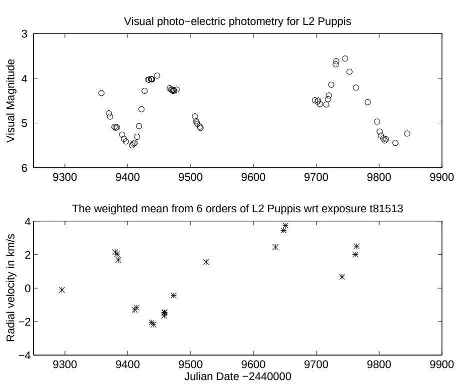
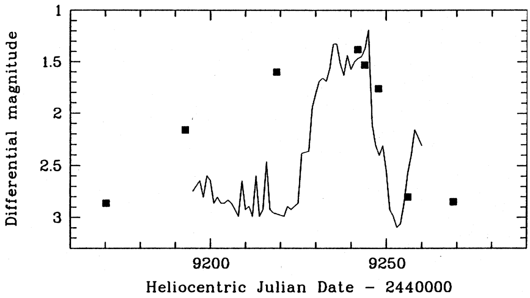


The correlation between brightness and velocity variations for the giant star L^2 Puppis. On the astronomical scale, the velocity variations are very small and require excellent instrumental stability to detect. They may arise owing to pulsation of the star. From: Cummings et al., *(1995).*



Correlation between optical emission measured at Mt John (squares) and X-ray emission (line) measured from the Compton Gamma-Ray Observatory satellite for the X-ray pulsar GX1+4. The 30-day delay between the optical and X-ray brightenings provide clues to the nature of the accretion discs in the system. From: Greenhill et al., *(1995).*

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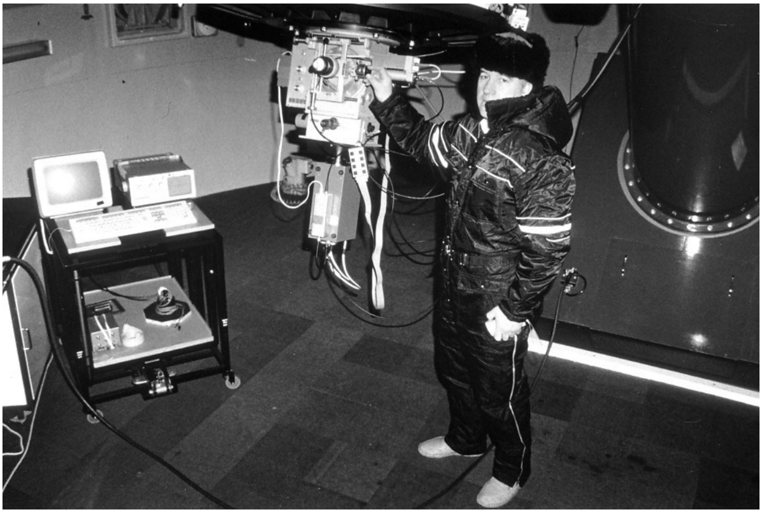
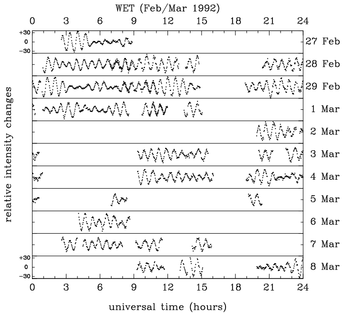
Astronomy & Astrophysics, **307**, 529-38 (1996)



You need to dress up warmly when observing! This is because domes are never heated in order to minimise optical distortions caused by rising warm air. Regular visiting observer Dr Denis Sullivan (Victoria University of Wellington) poses with his two-channel photometer mounted on the McLellan Telescope. Denis uses this photometer to participate in the Whole Earth Telescope *(WET). WET consists of telescopes around the globe that at prearranged times all observe the same object in an attempt to obtain continuous coverage.*



The overall light curve of a multi-periodic pulsating variable obtained during a WET 11-day observing campaign in 1992. The light variations are clearly more complicated than a simple sinusoid, and result from physical pulsations of the star at a number of different frequencies. The observations at different sections of each 24-hour period derive from different observatories around the world. The rising sun (always) and cloud (sometimes) interrupts observing at any particular observatory. The Mt John observations are in the 9 to 16 hour region. Adapted from: Handler et al.*, 1996. For a further example, see page 106.*

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In *IAU Colloquium No. 87 'Hydrogen deficient stars and related objects',* Hunger, K., Schönberner, D. & Kameswara Rao, N. (Eds.) , Reidel, 211-14 (1986)

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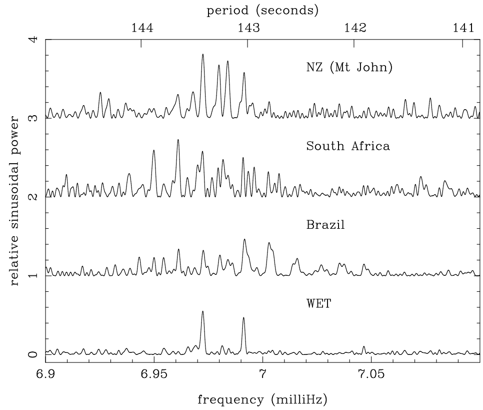

These graphs show the relative power at different frequencies (the power spectrum*) in the light curve of a pulsating white dwarf as measured by the Whole Earth Telescope using 3 observatories during a 9-day period in 1995. The interruptions due to dawn, clouds etc. confuse the power spectra derived from individual observatories. Combined, the data reveal that the white dwarf is pulsating with only two, well-defined frequencies in the plotted frequency range. From: Sullivan (1995b). See also page 98.*

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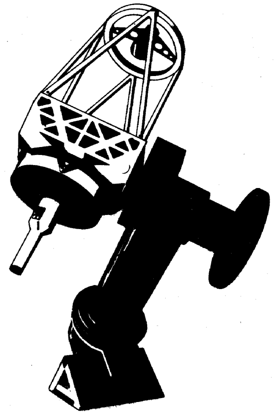

Research Notes

Author abbreviations

A:	W.H. Allen	G:	A.C. Gilmore	M:	V.J. McIntyre
Au:	R.R.D. Austin	Hr:	J. Haar	R:	P.W. Ratzlaff
B:	G.L. Blow	Hw:	J.B. Hearnshaw	Wa:	L. Watson
Bu:	D.A.H. Buckley	Kg:	W.M. Kissling	W:	G.W. Wolf
C:	M. Clark	Kn:	P.M. Kilmartin		
Ct:	P.L. Cottrell	L:	W.A. Lawson		

Other abbreviations

AS:	Astrometry	Na:	Nova(e)	PHY:	Physical obs.
C/:	Comet	OCC:	Occultation	REC:	Recovery
DIS:	Discovery	P/:	Periodic comet	SP:	Spectroscopy
MP:	Minor planet	PHO:	Photometry		

Information Bulletin on Variable Stars (IBVS)

IBVS	YEAR	AUTHORS	TITLE
1867	1980	Bu	Light curve of RS Scuti
3085	1987	L, Kn, G, C	UBV photometry of the R Coronae Borealis star RY Sgr — 1984 to 1986
3178	1988	L, Kn, G	UBV photometry of the R Coronae Borealis star GU Sgr — 1986/87
3214	1988	L, Kn, G	UBV photometry of R Cornoae Borealis
3407	1989	C	Radial velocities of some brighter southern stars
3872	1993	Kg, B, G	SAO 189111 in Sagittarius is an eclipsing binary
4018	1994	W, R	Times of minimum of eclipsing binaries in and near Centaurus

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IAUC	OBS'V'RS	OBSERVATIONS
1981		
3591	G, C	AS Nova CrA 1981
3601	G, Kn	AS C/Bus 1981d
3619	G, Kn	AS C/Gonzalez 1981g
3623	G, Kn	AS C/Gonzalez 1981g
3631	G, Kn	AS MP 1981 QA
3633	G, Kn	AS C/Howell 1981k
		Amor MP 1981 QB
3634	G, Kn	AS MP 1981 QB
3635	G, Kn	AS C/Howell 1981k
3637	G, Kn	AS MP 1981 QB

IAUC	OBS'V'RS	OBSERVATIONS
1982		
3672	G, Kn	AS P/du Toit-Hartley 1982b,c
3705	Au,G,Kn	DIS, AS C/Austin 1982g
3706	G, Kn	AS C/Austin 1982g
3708	G, Kn	AS C/Austin 1982g
3713	G, Kn	AS C/Hartley 1982h
3716	G, Kn	AS C/Austin 1982g
3717	G	PHY C/Austin 1982g
3721	G, Kn	AS C/Austin 1982g
3736	G, Kn	AS Na Sag 1982
1983		
3775	G, Kn	AS P/Bowell-Skiff 1983c
3808	G, Kn	AS C/IRAS-Araki-Alcock 1983d
3824	G, Kn	REC P/Johnson 1983h
3826	G, Kn	AS C/Sugano-Saigusa-Fujikawa 1983e
3831	G, Kn	AS C/IRAS 1983f
3837	G, Kn	As C/IRAS 1983j
3843	G, Kn	AS C/Cernis 1983l
3845	G, Kn	AS P/IRAS 1983j
3848	G, Kn	AS C/Cernis 1983l
3855	G, Kn	AS C/IRAS 1983k
3860	G, Kn	AS C/IRAS 1983o
3865	G, Kn	AS Apollo MP 1983 RD
3873	G, Kn	AS C/IRAS 1983o
3874	G, Kn	AS C/Shoemaker 1983p
1984		
3909	G, Kn	AS C/Bradfield 1984a
3949	G, Kn	AS C/Shoemaker 1984f
3954	G, Kn	AS Apollo MP 1984 KD
3955	G, Kn	AS P/Bradfield 1984a
3957	Au,C,Kn	DIS, AS C/Austin 1984i
3958	G, Kn	AS C/Austin 1984i
3960	G, Kn	AS C/Austin 1984i
3966	G, Kn	AS Amor MP 1982 RA
4016	G, Kn	AS C/Hartley 1984v
1985		
4048	G, Kn	REC P/Ashbrook-Jackson 1985a
4056	Kn, G	REC Apollo MP 1981 VA
4079	G, Kn	AS MP 1985 JA
4109	G, Kn	AS C/Hartley-Good 1985l
4113	G, Kn	AS C/Hartley-Good 1985l
4121	G, Kn	REC P/Boethin 1985n
4139	G, Kn	REC P/Wirtanen 1985q
1986		
4185	G, Kn	AS Apollo MP 1985 PA
4211	G, Kn	AS C/Singer Brewster 1986d
4214	G, Kn	AS C/Singer Brewster 1986d
4220	G, Kn	AS Apollo MP 1986 JK
1987		
4335	G, Kn	REC P/Howell 1987h
4352	Hw, Hr	SP SN1987A in LMC
4355	Hw, Hr	SP SN1987A in LMC
4363	Hw	SP SN1987A in LMC
4404	G, Kn	REC P/Borrelly 1987p
4409	G, Kn	REC MP 1981 FD
4416	G, Kn	AS Apollo MP 1959 LM = 1987 MB
4431	G	AS C/Bradfield 1987s
4433	G, Kn	AS C/Bradfield 1987s
4434	G, Kn	AS C/Bradfield 1987s
4454	G, Kn	AS Apollo MP 1987 QA
4456	Hw, M	SN1987A in LMC
1988		
4530	G, Kn	AS C/Liller 1988a
4580	Kn	PHO Na in LMC
4586	G, Kn	REC C/Finlay 1988f
4586	G, Kn	SP, PHO Na Oph
4589	G	PHO Na in LMC
4612	A,G,Kn	OCC by Pluto
4633	L,Kn,G	R CrB decline
4636	Ct, L	R CrB decline
4643	G, Kn	AS C/Machholz 1988j
4650	L,Kn,G, C	NSV 6708 decline
4671	L,Kn,G	V CrA decline
1989		
4749	G	AS C/Parker-Hartley 1989i
4750	G, Kn	AS C/Parker-Hartley 1989i
4778	L,Kn,G	S Apodis decline
4785	G, Kn	AS MP 1989 JA

IAUC	OBS'V'RS	OBSERVATIONS
4792	G, Kn	PHO WX Ceti outburst
4814	L,Kn,G	V854 Centauri = NSV6708 decline
4897	G, Kn	AS Aten MP 1989 UQ
4901	G, Kn	AS Apollo MP 1989 VB
4920	G, Kn	AS C/Austin 1989 c1
4921	G, Kn	AS C/Austin 1989 c1
1990		
4949	G, Kn	PHO LMC Na 1990
4956	G, Kn	PHO LMC Na 1990
4960	G, Kn	PHO LMC Na 1990
4970	Kn	MAG C/Austin
4975	G, Kn	PHO C/Austin
5000	Ct,L,G, Kn	Declines 4 R CrB-type stars
5044	G, Kn	AS Apollo MP 1990 MF
5050	G, Kn	AS Apollo MP 1990 MF
5056	G, Kn	AS Amor MP 1990 OA
5068	G, Kn	AS Apollo MP 1990 OS
1991		
5189	G, Kn	AS C/McNaught-Russell 1991g
5215	G, Kn	AS C/Helin-Lawrence 1991l
5216	G, Kn	AS Apollo MP 1991 DG
5238	G, Kn	AS Na Oph 1991
5286	G, Kn	REC P/Shoemaker 1 1991p
5293	G, Kn	AS C/Levy 1991q
5301	G, Kn	AS P/Machholz 1986 VIII
5315	G, Kn	AS Na Sgr
5318	G	PHO FG Ser
5319	G	PHO Na Oph 1991
5320	G	PHO Na Sag 1991
5321	G	PHO Na Cen 1991
5324	G	PHO Na Sag 1991
5333	G	PHO Na Cen, Oph & Sgr
5344	G, Kn	AS Apollo MP 1991 RB
1992		
5422	G, Kn	PHO & AS Na Pup 1991
5430	G	PHO Na Pup 1991
5445	G, Kn	AS C/Bradfield 1992b

IAUC	OBS'V'RS	OBSERVATIONS
5454	G	PHO Na Sag 1992
5455	G	PHO Na Pup 1991
5469	G, Kn	PHO C/Bradfield1992b
5483	G	PHO Na Pup 1991
5493	G	PHO Na Pup 1991
5502	G, Kn	PHO HV Vir
5503	G, Kn	AS HV Vir
5514	G, Kn	AS C/Bradfield 1992i
5527	G, Kn	PHO Na Pup 1991
5528	G, Kn	AS Na Sco 1992
5530	G, Kn	AS C/Bradfield 1992i
5546	G, Kn	REC P/Ashbrook-Jackson 1992j
5546	G, Kn	PHO Na Sco 1992
5552	G	PHO Na Pup 1991
5555	G	PHO Na Sco 1992
5561	G	PHO Na Sco 1992
5566	G	PHO Na Sag 1992 No.2
5574	G	PHO Na Sco 1992
5576	G	PHO Na Sag 1992 No.2
5626	G	PHO Na Sco 1992
5628	G	PHO Na Pup 1991
5630	G, Kn	AS SN 1992ba in NGC 2082
5633	G	PHO Na Sag 1992 No.2
5642	G	PHO Na Sag 1992 No.3
5647	G	PHO Na Sag Nos.2&3
5655	G	PHO Na Pup 1991
5659	G	PHO LMC Na 1992
5661	G	PHO LMC Na 1992
5666	G	PHO Na Pup 1991
5669	G	PHO Na Pup 1991
5683	G	PHO LMC Na 1992
1993		
5711	G, Kn	AS Amor MP 1993 BX3
5764	Kn,G,Ct	S Aps decline
5766	G	PHO Na Oph 1993
5781	G	PHO V351 Pup (Na Pup 1991)
5784	G	PHO Na Oph 1993
5791	G, Kn	PHO EX Lup
5863	Kn, G	AS PHO Na Sag 1993
5872	G	PHO Na Sag 1993

IAUC	OBS'V'RS	OBSERVATIONS	IAUC	OBS'V'RS	OBSERVATIONS
5875	G, Kn	Possible OCC by Pluto-Charon	6013	G	PHO Na Oph 1994
			1995		
5891	G	PHO Na Sag 1993	6130	G, Kn	PHO, AS 3 Na
1994			6131	G, Kn	PHO, AS 3 Na
5943	G, Kn	PHO, AS Na Sag 1994	6139	G, Kn	PHO, AS 3 Na
5944	Kn, G	AS + PHO Na Sag 1994	6139	Hw, Wa	SP Na
5949	G	PHO Na Sgr 1994	6140	G, Kn	PHO, AS 3 Na
6002	G	PHO Na Oph 1994	6141	G, Kn	PHO, AS 3 Na
6004	G	PHO C/Mueller 1993p	6144	G, Kn	PHO, AS 3 Na
6009	G, Kn	REC P/Borrelly 1994l	6145	Kn	PHO, AS 3 Na

Minor Planet Circulars (MPC)

Astrometric positions of **comets** by A.C. Gilmore & P.M. Kilmartin appear in the following MPCs:

5257, 5340, 5823, 5927, 5989-91, 6146, 6227, 6488-89, 6581, 6657, 6842, 6991, 7056-58, 7168-70, 7879, 7998-99, 8035-37, 8086, 8088-90, 8187, 8219-21, 8324, 8485-86, 8594, 8596-97, 8829-32, 8964, 9042, 9175-77, 9254-55, 9257, 9316-18, 9442, 9516, 9722, 9815-17, 9991, 9993-94, 10076, 10078-81, 10198-200, 10222-23, 10226-27, 10460, 10475-77, 10671, 10675-76, 11208, 11468-69 11683, 11686-87, 11779, 11781, 11895, 12032-33, 12169, 12365, 12500, 12750, 12854, 12856-62, 13111, 13361, 13358, 13360-61, 13364, 14234, 14386, 14521, 14821, 15133, 15286, 15946-47, 16124, 16654, 17683-85, 17984, 17988, 18010-14, 18491 18494-96, 19068-69, 19565, 19728, 19731, 19913-15, 20071, 20195, 20369-72, 20671, 21983, 22115-16, 22119, 22612-13, 23262, 23352, 23552, 23561, 23698, 23710, 23884, 24136, 24600

Astrometric positions of **asteroids** or **minor planets** by A.C. Gilmore & P.M. Kilmartin appear in the following MPCs:

3883, 4023, 4033, 4151, 4194, 4300, 4302, 4570, 4814, 5120, 5257, 5823, 5948, 5996, 6073, 6409, 6496, 6589, 6859, 7104, 7198, 7332, 7429, 8010, 8045, 8114, 8248, 8508, 8619, 8753, 8865, 9009, 9052, 9189, 9264, 9327, 9528, 9656, 9729, 9821, 9937, 9998, 10090, 10270, 10484, 10802, 11218, 11313, 11486, 11703, 11799, 11915, 12038, 12282, 12408, 12764, 12902, 13126, 13384, 14426, 14559, 14724, 14846, 14991, 15159, 15496, 15965, 16663, 16799, 16952, 17521, 17705, 17871, 18031, 18181, 18335, 18510, 18676, 18876, 19162, 19403, 19589, 19751, 19941, 20087, 20381, 20693, 20997, 21691, 21862, 22007, 22144, 22303, 22445, 22631, 22735, 22847, 23020, 23176, 23284, 23388, 23580, 23716, 23817, 23903, 24036, 24153

Theses

PHD THESES
(COMPLETE LIST, INCLUDING THEORETICAL AND RADAR ASTRONOMY)

Gilmore, G.F. (1979)
Observational extragalactic astronomy: An investigation of southern quasars and related objects

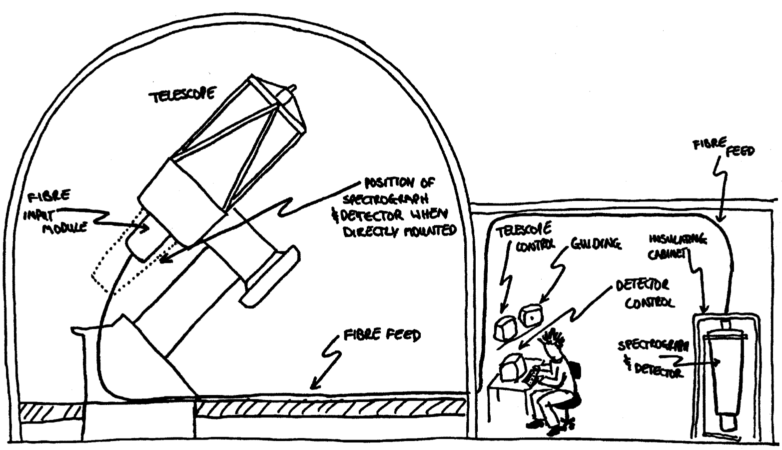
Collier, A.C. (1982)
Late-type Ca II emission-line stars in the southern hemisphere

Steel, D.I. (1984)
Orbital characteristics of meteoroids

MacQueen, P.J. (1986)
Solid-state image detector development: a Linear Diode Array for astronomical spectroscopy

Lawson, W.A. (1990)
The characteristics of cool hydrogen deficient carbon stars

Taylor, A.D. (1991)
A meteor orbit radar



The McLellan One-metre Telescope and échelle spectrograph linked by an optical fibre. Very precise measures of stellar radial velocity are possible when the spectrograph is in a thermostatted enclose and not subject to varying flexure as the telescope moves. From: Murdoch (1992).

Murdoch, K.A. (1992)
A high-precision radial-velocity search for substellar companions to southern solar-type stars

Easther, R.J.M. (1993)
The evolution of scalar fields and inflationary cosmology

Albrow, M.D. (1994)
Metallic line profiles in Cepheid variables

Pollard, K.R. (1994)
The nature of the low mass supergiants: RV Tauri and R Coronae Borealis variables

MSc THESES
(INCLUDING THEORETICAL TOPICS)

McDonald, A.R.E. (1981)
An analysis of the Wolf 630 and Arcturus moving groups of stars

Soonthornthum, B. (1981)
An abundance analysis of the high-velocity star ω Pavonis

Buckley, D.A.H. (1982)
Observations and interpretations of some neglected eclipsing binaries

Mowat, M.C.K. (1982)
Surface gravities of red giant stars

Noordanus, B.G. (1983)
A spectroscopic and photometric analysis of the nature of HR 5637

Begley, M. (1985)
Light element abundances in the Galactic disk

Lawson, W.A. (1985)
RY Sgr: Photometric and spectroscopic pulsations

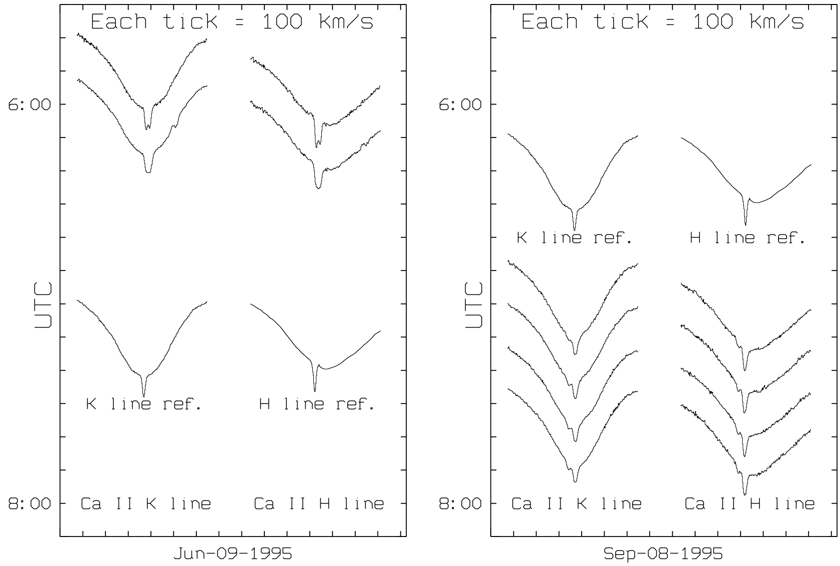
Reynolds, S.A. (1986)
The r- and s-process elements in the spectrum of Canopus

McIntyre, V.J. (1988)
Optical spectroscopy of supernova SN 1987A in the Large Magellanic Cloud—The first year

Haar, J.L. (1989)
Effective temperature calibration of B-type halo stars

West, S.R.D. (1991)
CCD photometry of HV 2208 and other eclipsing binaries in the Magellanic Clouds

Wadsworth, A. (1991)
A variable star search of ESO Key Programme regions in the Magellanic Clouds



High-resolution spectroscopy of the H and K absorption lines of singly-ionized calcium in the spectrum of the southern star β Pictoris. This star is thought to be in the stage of planet formation where planets have formed but the surrounding disc of protoplanetary matter has not yet cleared away. The broad stellar H and K absorptions are overlain by a constant narrow absorption caused by circumstellar gas in the disc. Variable absorptions are also seen, which are believed to be caused by comet-like bodies falling in on β Pictoris and evaporating. The 'ref' spectra indicate the appearance of the H and K lines in the absence of any infall. From: Petterson (1996).

Ward, D-M. (1992)
A study of the variability of southern late-type supergiants using an échelle radial-velocity spectrometer

Frame, D.J. (1993)
Extremely hygdrogen-deficient binary stars

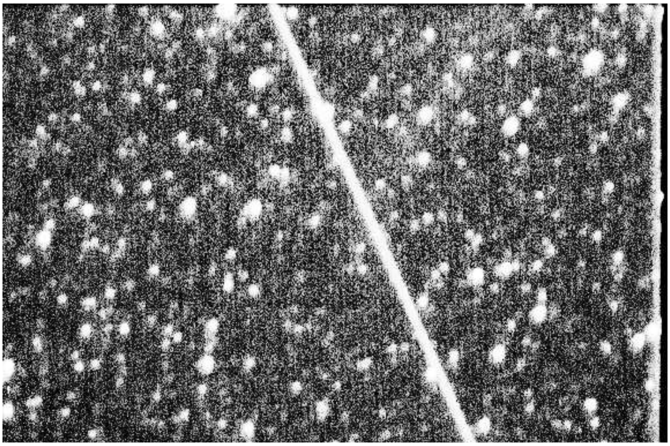
Watson, L.C. (1993)
Measurement of stellar radial velocities using the Lucifers radial-velocity spectrometer

Wilkins, A.H. (1994)
Cosmic strings

Petterson, O.K.L. (1996)
Ca II absorption in the circumstellar disk of Beta Pictoris and other A-type stars

Photometrics CCD system: Use and Performance Notes

No. 1: Tobin, W.,* 1990, *Description of the system.*
No. 2: Pollard, K.R.,* 1989, *Evaluation of the linearity of the Mt John CCD.*
No. 3: Pollard, K.R.,* 1989, *Evaluation of the spectral response for various operating temperatures of the Mt John CCD.*
No. 4: Hugtenburg, R.,* Tobin, W.,* 1990, *Flexure tests of the Mt John Boller & Chivens spectrograph as temporarily modified with a telephoto camera lens for use with the Photometrics CCD detector system.*
No. 5: Gilmore, A.C.,* Tobin, W.,* 1991, *Temperature sensitivity of the CE200 electronics unit.*
No. 6: Tobin, W.,* *The Boller & Chivens intermediate resolution spectrograph.*
No. 7: Tobin, W.,* 1991, *Time keeping on the Photometrics CCD system.*
No. 8: Tobin, W.,* 1991, *Forth acquisition software.*
No. 9: Tobin, W.,* 1992, *Problems of CCD flat fielding.*
No. 10: Tobin, W.,* 1992, *Gain, noise and related characteristics of the Mt John Photometrics CCD system.*
No. 11: Tobin, W.,* 1993, *Shutter map.*
No. 12: Pritchard, J.D.,* 1993, *McLellan Telescope f/8 seeing values in the green.*
No. 13: Tobin, W.,* 1993, *Christchurch VMS-based software.*
No. 14: Pritchard, J.D.,* 1993, *Forth commands implemented by the file JDP.*
No. 15: Tobin, W.,* 1993, *TH7882 quantum efficiency.*
No. 16: Tobin, W.,* 1993, *Atlas of typical and atypical images.*



Orbiting satellites are easy to see at dusk and dawn, and even leave trails in the occasional CCD image. From: Use & Performance Note No. 16.

About Mt John University Observatory

Anon.
Mt John University Observatory and Astronomy Section of the Department of Physics
Publications (1961–1979), Christchurch (n.d.)

Hearnshaw, J.B.* & England, M.N.*
Infrared spectroscopy at Mt John Observatory
Southern Stars, **28**, 88 (1979)

Wood, F.B.
First Asian-South Pacific regional meeting of IAU
Comments on Astrophysics, **8**, 163-6 (1979)

Hearnshaw, J.B.*
Mt John University Observatory. Annual Report for 1979.
Southern Stars, **28**, 137-9 (1980)

Hearnshaw, J.B.*
The Mt John One-Metre telescope project
Southern Stars, **28**, 146-57 (1980)

Clark, M.*
New photographic sky patrol at Mt John
Southern Stars, **28**, 209-14 (1980)

Hall, D.A.
Silicon "eyes" for Mt John
Southern Stars, **29**, 67-77 (1981)

Hearnshaw, J.B.*
Mt John University Observatory. Report for 1980.
Southern Stars, **29**, 21-3 (1981)

McLellan, A.G.*
Astronomy at the University of Canterbury Physics Department and Mt John University Observatory. Report for 1981.
Southern Stars, **29,** 145-50 (1982)

Kershaw, G.M.* & Hearnshaw, J.B.*
Progress on the Mt John 1-metre telescope
Southern Stars, **30**, 304-6 (1983)

McLellan, A.G.*
Physics Department and Mt John University Observatory, The University of Canterbury. Report for 1982
Quarterly Journal of the Royal Astronomical Society, **24**, 462-5 (1983) and
Southern Stars, **30**, 269-73 (1983)

Wybourne, B.G.*
Physics Department and Mt John University Observatory, University of Canterbury. Annual Report 1983
Quarterly Journal of the Royal Astronomical Society, **25**, 494-7 (1984) and
Southern Stars, **30**, 462-6 (1984)

Wybourne, B.G.*
Physics Department and Mt John University Observatory, University of Canterbury. Annual Report 1984
Quarterly Journal of the Royal Astronomical Society, **27**, 120-3 (1986)

Wybourne, B.G.*
Physics Department and Mt John University Observatory, The University of Canterbury. Annual Report 1985
Quarterly Journal of the Royal Astronomical Society, **27**, 626-30 (1986)

Hearnshaw, J.B.*
The Mt John 1-metre telescope project
Astrophysics & Space Science, **118**, 79-81 (1986)

Wybourne, B.G.*
Physics Department and Mt John University Observatory, University of Canterbury, N.Z. Annual Report 1986
Quarterly Journal of the Royal Astronomical Society, **29**, 81-3 (1988) and
Southern Stars, **32**, 130-3 (1987)

Wybourne, B.G.* & Tobin, W.*
Astronomy at the University of Canterbury Physics Deparment and the Mt John University Observatory. Annual Report 1987
Quarterly Journal of the Royal Astronomical Society, **29**, 561-4 (1988) and
Southern Stars, **32,** 239-43 (1988)

Wybourne, B.G.* & Tobin, W.*
Astronomy at the University of Canterbury Physics Department and the Mt John University Observatory. Annual Report 1988
Quarterly Journal of the Royal Astronomical Society, **30**, 477-82 (1989) and
Southern Stars, **33**, 242-8 (1990)

Syme, R.W.G.* & Cottrell, P.L.*
Astronomy at the University of Canterbury Physics Department and Mt John University Observatory. Annual Report 1989
Quarterly Journal of the Royal Astronomical Society, **31**, 607-11 (1990) and
Southern Stars, **33**, 309-13 (1990)

Tobin, W.*
A CCD for Mt John
Southern Stars, **34**, No. 3, 155-158 (1991)

Cottrell, P.L.* & Hearnshaw, J.B.*
Astronomy at the University of Canterbury Physics Department and Mt John University Observatory. Annual Report 1990
Quarterly Journal of the Royal Astronomical Society, **33**, 375-9 (1992) and
Southern Stars, **34**, 407-11 (1992)

Hearnshaw, J.B.*
Astronomy at the University of Canterbury Physics Department and Mt John University Observatory. Report for 1991
Quarterly Journal of the Royal Astronomical Society, **33**, 381-5 (1992) and
Southern Stars, **34**, 412-7 (1992)

Hearnshaw, J.B.*
On top of the World, down South: New Zealand's Mt John Observatory
Southern Astronomy, **5** (No. 2), 12-16 (1992)

Hyde, V.
Godzone Skies : astronomy for New Zealanders
Canterbury University Press, Christchurch (1992)

Hearnshaw, J.B.*
Astronomy at the University of Canterbury Department of Physics and Astronomy and Mt John University Observatory–Annual Report 1992
Quarterly Journal of the Royal Astronomical Society, **35**, 123-8 (1994) and
Southern Stars, **35**, 117-122 (1993)

Cottrell, P.L.*
Astronomy at the Mt John University Observatory and the Department of Physics and Astronomy at the University of Canterbury–Annual Report 1993
Quarterly Journal of the Royal Astronomical Society, **36**, 153-60 (1995) and
Southern Stars, **36**, 211-7 (1995)

Cottrell, P.L.*
Astronomy at the Mt John University Observatory and the Department of Physics and Astronomy at the University of Canterbury–Annual Report 1994
Southern Stars, **36**, 218-24 (1995)

Hearnshaw, J.B.*
Thirty years of New Zealand research in astronomy
The Australian and New Zealand Physicist, **32**, 183-7 (1995)

Sharp, I.
Seeing stars
Pacific Way, **89**, 82-6 (1995)

Publications for a wider public

Hearnshaw, J.B.*
Canopus
Southern Stars, **30**, 290-7 (1983)

Kilmartin, P.M.*
What's in a name – II. Minor planet nomenclature revisited
Southern Stars, **30**, 298-303 (1983)

Gilmore, A.C.* & Kilmartin, P.M.*
New Zealand asteroid discoveries to 1983
Southern Stars, **30**, 391-400 (1984)

Hearnshaw, J.B.*
William Huggins and astronomical spectroscopy
Southern Stars, **31**, 17-22 (1984)

Begley, M.J.* & Cottrell, P.L.*
Stellar spectrum synthesis
Southern Stars, **31**, 161-72 (1985)

Cottrell, P.L.*
Globular clusters – homogeneous entities?
Southern Stars, **31**, 142-52 (1985)

Hearnshaw, J.B.*
William Huggins und die Anfänge der astronomischen Spektroskopie
Sterne und Weltraum, **24**, 140-42 (1985)

Hearnshaw, J.B.*
Astrophysics in the Orient
Southern Stars, **32**, 73-86 (1987)

Tobin, W.*
Foucault's giant Marseilles reflector
Sky & Telescope, **74**, 358-359 (1987)

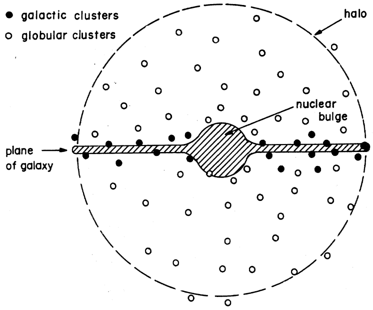
Hearnshaw, J.B.* & Tobin, W.*
Winter School in Astronomy – University of Canterbury—15-20 May 1988
NZ Science Teacher, No. 58, 6-7 (1988)

Tobin, W.*
The night sky in 1988
NZ Science Teacher, No. 56, 6-7 (1988)

Cottrell, P.L.*
Tertiary astronomy programs in New Zealand
Proceedings of the Astronomical Society of Australia **9**, 172-3 (1991)

Hearnshaw, J.B.*
Doppler and Vogel – two notable anniversaries in stellar astronomy
Vistas in Astronomy, **35**, 157-77 (1992)

Galactic (or open) star clusters are found close to the disc of the Milky Way. Open clusters are young, sparse and loose; the Jewel Box is an example (see pages 28 and 83). In contrast, Globular clusters, which are old, populous and tightly-condensed, swarm in a much less-flattened cloud around the Galaxy. From: Cottrell (1985).



Hearnshaw, J.B.*
Pogson's proposal and the origins of the magnitude scale
Sky and Telescope, **84**, 494-99 (1992)

Tobin, W.*
The Oxford Illustrated Encyclopedia, Vol. 8: The Universe
Roy, Prof. A.E. (Ed.), Oxford University Press, Oxford (1992)
Entries by W. Tobin: Angular measure; Astrometry; Black body; Bode's Law; Canopus; CCD camera; Colour index; 61 Cygni; Effective temperature; European Southern Observatory; Foucault's knife-edge test; Foucault's pendulum; Galactic halo; Gould Belt; Jewel Box; Kuiper Airborne Observatory; Le Verrier; Light year; Local group of galaxies; Magellanic Clouds; Occultation; Opacity; Optical depth; Paris Observatory; Parsec; Parallax; Photometer; Photometry; Photosphere; Planck's law; Siding Spring Observatory; Speckle interferometry; Spectral line; Stefan's law; Stephan's quintet; Stellar temperature; Velocity of light; Wien's displacement law.

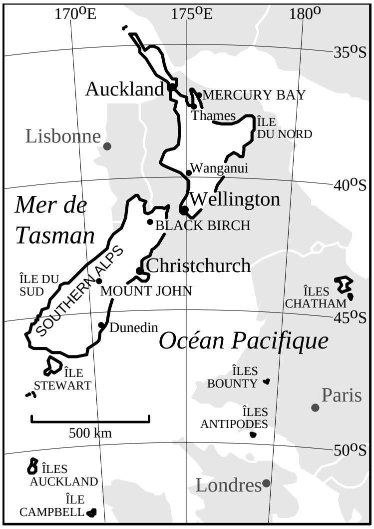
Banks, T.
CCD Images – after collection then what?
Southern Stars, **35**, 33-45 (1993)

Hearnshaw, J.B.*
The Encyclopedia of Cosmology
Hetherington, N.S. (Ed.), Garland Publishing, New York (1993)
Entries by J.B. Hearnshaw: Doppler; Fraunhofer; Huygens; Kirchhoff; Scheiner; Spectroscopy and Cosmology; Spectrum; Vogel.

Hearnshaw, J.B.*
Cosmology: Historical, literary, philosophical, religious, and scientific perspectives
Hetherington, N.S. (Ed.), Garland Publishing, New York (1993)
Entry by J.B. Hearnshaw: Spectroscopy.

Blow, G.L.
Just when you thought it was safe to forget about asteroidal satellites
Occultation Newsletter, **3**, 87-90 (1994)

Hearnshaw, J.B.*
What's new in stellar radial velocities?
Southern Sky, No. 3, 25-26 (1994)



New Zealand: its antipodes and sites of astronomical significance. From: Tobin (1995).

Hearnshaw, J.B.*
Celebration of New Zealand astronomy
Southern Sky, No. 6, 5 (1994)

Tobin, W.*
Sizing up stars in the Magellanic Clouds
Southern Sky, No. 8, 48-49 (1994)

Clark, M.
Software review: Project Pluto
Southern Stars, **36,** 165-8 (1995)

Love, T.*
The Comet Crash at Mt John
Southern Sky, No. 11, May/Jun (1995)

Tobin, W.*
L'astronomie aux antipodes
L'astronomie, **109**, 261-9 (1995)

Tobin, W.* & Chevalier, G.
Le Grand Art des Pièges à Lumière
Les Cahiers de Science & Vie, No. 25, 50-67 (1995)

Tobin, W.*
Foucault, son pendule, et la rotation de la Terre
L'astronomie, **110**, 50–60 (1996)

Dodd, R., Hearnshaw, J.B.,* Sullivan, D. & Yock, P.
MOA seeks MACHO companions
New Zealand Science Monthly, **7,** No. 4, 6-7 (1996)

Articles and newspaper articles concerning Canterbury astronomers

The bold header gives the name the person featured; the author, if different, is noted in [square brackets].

Austin, Rodney
The comet hunter [Wright, V.]
New Zealand Listener 1 April 1984.

Bateson, Frank
Paradise Beckons The Heritage Press, Waikanae (1989).
The Variable Star Section, RASNZ
Sky & Space **6,** No. 2, 37-39 (1993).
Frank Bateson—A passion for the stars [Nelson, P.]
Southern Sky No. 3, 27-28 (1994).

Bickerton, Alexander
Alexander William Bickerton: New Zealand's Colourful Astronomer [Gilmore, G.]
Southern Stars **29,** 87-108 (1982).

Cottrell, Peter
Today's Astronomers
Southern Sky No. 2, 12-13 (1993).

Hearnshaw, John
Nocturnal confessions of a Kiwi astronomer
Southern Sky No. 9, 38-9 (1995)

Kilmartin, Pam
Astronomer honoured [Malthus, N.]
The Press (Christchurch) 31 May 1989.

Murdoch, Kaylene
Woman on track of new planets [Paine, J.]
The Christchurch Star 28 April 1989.
Brown dwarfs hunt in outer space [Airey, M.]
The Press (Christchurch) 28 June 1989.

Tinsley, Beatrice
Appreciation: Beatrice M. Tinsley 1941-1981 [Dodd, R.J.]
Southern Stars **30,** 429-431 (1984).
My daughter Beatrice [Hill, E.]
American Physical Society, New York (1986).
American astronomers honour a brilliant career
The Press (Christchurch) 11 January 1986.

Other newspaper articles

This section lists (1) articles authored by Department of Physics & Astronomy personnel, or (2) selected articles concerning Mt John and Canterbury astronomy.

Author abbreviations (authors unassociated with the University of Canterbury are omitted):

B:	E. Beardsley	L:	M. Lauren*	S:	C. Sterken
G:	A.C. Gilmore*	Ms:	J.S. Mathis	T:	W. Tobin*
Hw:	J.B. Hearnshaw*	P:	J.D. Pritchard*	W:	B.G. Wybourne*

Newspaper abbreviations:

Pr:	The Press (Christchurch)	St:	The Christchurch Star	TH:	The Timaru Herald

Date	Paper	Author	Title
1981			
Mar 7	TH	G	Looking Toward the Heavens
Apr 4	TH	G	Look for the ‘Saucepan’
May 9	TH	G	Southern Cross easy to find
May 19	Pr		A new telescope [editorial]
June 16	TH	G	Scorpius the Scorpion
July 7	TH	G	Planetary ‘alignment’
Aug 5	TH	G	First N.Z. discovery of an asteroid
Aug 8	TH	G	Venus – the evening star
Aug 29	TH	G	A gathering in the evening sky
Oct 10	TH	G	Scorpion, Archer and Crown
Nov 14	TH	G	The Milky Way and nearby galaxies
Nov 27	Pr	B	N.Z.’s largest telescope big step nearer completion
Dec 11	TH	G	The Hunter and the Saucepan
1982			
Jan 16	TH	G	Taurus and the Seven Sisters
Feb 27	TH	G	Sirius the brightest star
Apr 3	TH	G	Mars, Jupiter and Saturn
May 15	TH	G	The Zodiac
June 12	TH	G	The Cross and the Pointers
July 2	TH	G	Total eclipse of moon on Tuesday night
July 12	Pr		Work on big telescope at Tekapo going well
July 30	TH	G	Comet Austin returns to NZ skies
Aug 7	TH	G	Comet Austin passes by
Sep 18	TH	G	Some Northern Stars
Oct 29	TH	G	Halley’s Comet seen for the first time since 1910

Date	Paper	Author	Title
Nov 6	TH	G	The Milky Way in November
Dec 18	TH	G	The Hunter and the Bull
Dec 30	TH	G	Total eclipse of moon tonight
1983			
Jan 29	TH	G	Sirius in the east heads 'the Summer Triangle'
Feb 19	TH	G	Two bright stars nearly overhead
Mar 19	TH	G	Argo, 'the ship that carried the gods'
Apr 16	TH	G	Gemini, Cancer and Leo
May 11	TH	G	Comet will make closest approach to earth tonight
May 14	TH	G	Five million kilometres away and comet becomes visible
May 14	TH	G	Jupiter – the golden star
June 11	TH	G	Another comet comes close
June 14	St		Mt John tracking station to close
June 15	Pr		Mt John to close in September
June 15	Pr		U.S. station on Mt John [editorial]
June 15	TH		Baker Nunn tracking station to close
June 23	TH	G	Last chance to see lunar eclipse until 1986
July 9	TH	G	Horse man in the sky
Aug 13	TH	G	UFO reports likely during 'transit of Venus'
Sep 10	TH	G	Jupiter a highlight of September
Sep 27	St		University to help build telescope
Sep 29	St		Astronomy dome takes shape
Oct 8	TH	G	Little planets whizz by
Nov 5	TH	G	Moon and Jupiter close on Monday
Nov 7	TH		University seeks lease of Mt John station
Dec 3	TH	G	The nearest galaxies
1984			
Jan 7	TH	G	The Seven Sisters
Jan 14	Pr	B	Mount John has major role to play in observing Halley's Comet
Jan 20/21	TH	B	Major observation role for Mt John
Feb 4	TH	G	Taurus – The Bull
Mar 3	TH	G	Orion – The Hunter
Apr 7	TH	G	Leo the Lion
May 5	TH	G	Mars nearby this month
June 2	TH	G	The Scorpion reappears
July 7	TH	G	Jupiter in Sagittarius
July 11	TH	G	Rare second-comet find for New Plymouth man
July 21	TH	G	Comet Austin visible through binoculars
Aug 4	TH	G	Hercules, the Crown and the Harp
Sep 1	TH	G	Uranus – the seventh planet
Aug 30	TH	G	Saturn behind moon

Date	Paper	Author	Title
Oct 6	TH	G	Planets only look to be close to each other
Oct 12	Pr		University gets Mt John station lease
Nov 10	TH	G	Solar eclipse on 23 November
Dec 1	TH	G	Clouds of Magellan
1985			
Jan 5	TH	G	One of finest sights in sky for amateurs
Feb 9	TH	G	Bright evening star on the move
Mar 9	TH	G	Gemini and other twins
Apr 6	TH	G	Many bright stars along the Milky Way
Apr 20	TH	G	Lunar eclipse note
May 11	TH	G	The Southern Cross and imitations
June 8	TH	G	Saturn most remote of naked-eye planets
July 13	TH	G	Halley's Comet will begin to emerge in August
Aug 10	TH	G	Jupiter well named as the chief planet
Aug 27	Pr		Observatory nearing completion
Sep 14	TH	G	Spacecraft meets planet
Sep 21	Pr	Hw	Journey in space with maps
Oct 12	TH	G	Nearby galaxies
Nov 9	TH	G	Halley's Comet on target
Nov 30	Pr	B	University's new telescope on show to nations
Dec 7	TH	G	Look for Halley's Comet
1986			
Jan 4	TH	G	Jupiter brightest object in evening sky
Feb 15	TH	G	Halley's Comet appears soon
Feb 21	TH	A	Telescope that can see forever...
Mar 4	Pr	S	Halley's Comet photographed
Mar 5	TH	G	Halley's Comet visible to unaided eye
Apr 5	TH	G	Halley's Comet closest on Friday
Apr 6	W	Pr	What is the use of astronomy?
May 10	TH	G	Halley's Comet – Worst recorded appearance since 240 BC
June 14	TH	G	Moon passes in front of Mars
July 12	TH	G	Voyager 2 made vital discoveries
July 30	Pr		Looking into history – through the Mt John telescope
Aug 16	TH	G	Bright planets dominate evening sky
Sep 16	TH	G	Bright planets take pride of place
Oct 11	TH	G	Venus prominent in the western sky
Nov 20	TH	G	Jupiter prominent in the eastern sky
Dec 9	TH	G	A new star appears in Centaurus
1987			
Jan 3	TH	G	Summer constellations now on show
Feb 26	TH	G	NZ astronomers involved in find [Supernova 1987A]

Date	Paper	Author	Title
Mar 2	TH	G	Supernova very close – relatively
June 18	TH	G	Winter constellations in evening sky
Aug 14	Pr		Death throes of a giant star
Oct 9	TH	G	Supernova catches attention
Nov 24	TH	G	Venus, Jupiter dominate evening sky
1990			
Mar 3	TH	G	Venus, Mars and Saturn close together in the morning sky
Mar 24	TH	G	New comet will be a little late in arriving
Apr 27	Pr	T	A new eye on deep space
Sep 13	TH	G	Comet Levy hoves into view
1991			
June 17	TH	G	Planets make a bright threesome
1992			
Jan 4	Pr	Hw	Coming of age in the Milky Way
May 16	Pr	Hw	The natural history of the universe
July 10	TH	G	Giotto to view NZ-linked comet
July 17	TH	G	Giotto spacecraft passes close to comet
July 29	Pr	T	Magellanic Clouds view exploited
Dec 26	Pr	Hw	Frontier of science
Dec 26	Pr	T	20th century physics
1993			
May 25	Pr	Ms,T	Space frontiers open up despite flawed telescope
June 3	TH	G	Full lunar eclipse
1994			
March 12	Pr	Hw	Wrinkles in time
July 19	Pr		Observing the crash from Mt John
July 27	Pr	L	Mt John scientists pick out Jupiter spot
1995			
Apr 11	Pr	T	Metric system to celebrate 200th birthday
June 10	Pr	T	Flying telescope may have its wings clipped
1996			
Jan 2	Pr	P	The day the sky dragon swallowed the Sun

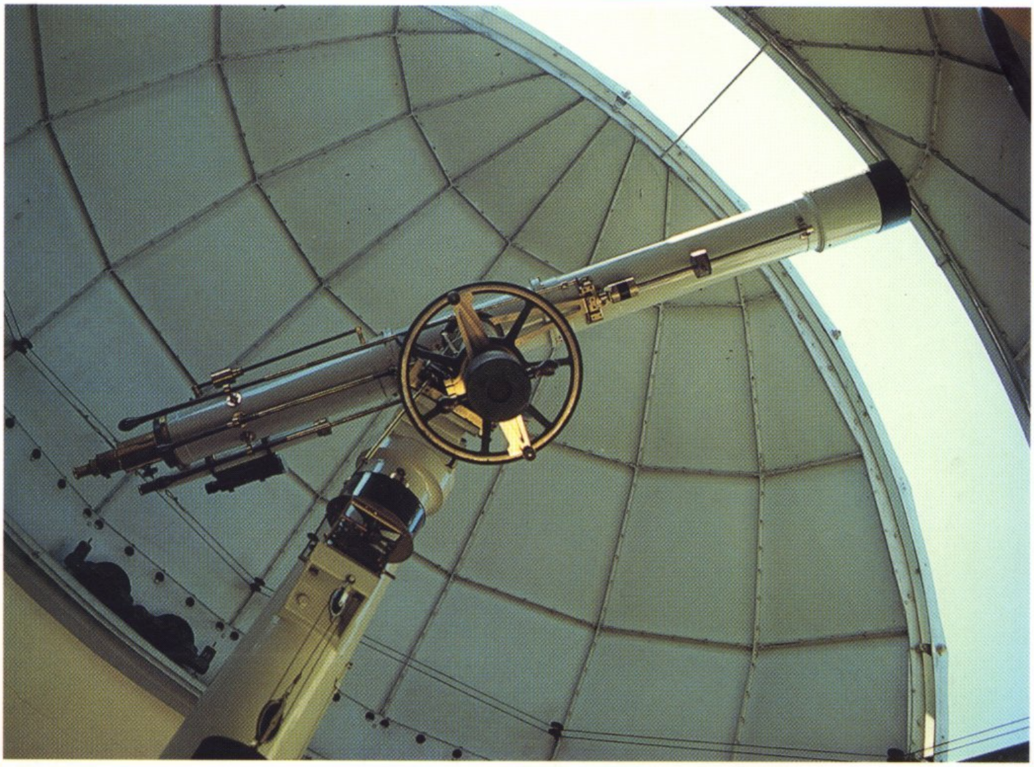
PDF version produced in 2014 by William Tobin.

Several photographs that were reproduced in black & white in the original printed edition have been inserted in colour.

A handful of mostly typographical errors have been corrected.

The Townsend Tower was damaged in the Christchurch-Darfield earthquake on 2010 September 4 and along with the Townsend Telescope fell in the Christchurch-Lyttelton earthquake on 2011 February 22.

Department of Physics & Astronomy
University of Canterbury
Private Bag 4800
Christchurch 8140
New Zealand



Mt John University Observatory

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10th Anniversary of the McLellan Telescope

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100th Anniversary of the Townsend Telescope

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Publications 1979–1995

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Department of Physics and Astronomy
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